



US011362105B2

(12) **United States Patent**
Song et al.

(10) **Patent No.:** **US 11,362,105 B2**
(45) **Date of Patent:** **Jun. 14, 2022**

(54) **VERTICAL MEMORY DEVICE WITH
SUPPORT LAYER**

(56) **References Cited**

U.S. PATENT DOCUMENTS

(71) Applicant: **SAMSUNG ELECTRONICS CO.,
LTD.**, Suwon-si (KR)

8,476,688 B2 7/2013 Cho et al.
8,847,302 B2 9/2014 Alsmeyer et al.
9,281,316 B2 3/2016 Lee
9,306,041 B2 4/2016 Hwang et al.

(Continued)

(72) Inventors: **Seungmin Song**, Hwaseong-si (KR);
Kangmin Kim, Hwaseong-si (KR);
Joongshik Shin, Yongin-si (KR);
Geunwon Lim, Yongin-si (KR)

FOREIGN PATENT DOCUMENTS

(73) Assignee: **SAMSUNG ELECTRONICS CO.,
LTD.**, Suwon-si (KR)

KR 10-0929642 11/2009

OTHER PUBLICATIONS

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

Office Action dated Mar. 7, 2022 in corresponding German Patent
Application No. 10 2020 115 239.6 (17 pages).

Primary Examiner — Ismail A Muse

Assistant Examiner — Gustavo G Ramallo

(74) *Attorney, Agent, or Firm* — F. Chau & Associates,
LLC

(21) Appl. No.: **16/902,489**

(22) Filed: **Jun. 16, 2020**

(65) **Prior Publication Data**

US 2021/0134831 A1 May 6, 2021

(30) **Foreign Application Priority Data**

Oct. 30, 2019 (KR) 10-2019-0136325

(51) **Int. Cl.**

H01L 27/11565 (2017.01)

H01L 27/11582 (2017.01)

H01L 27/1157 (2017.01)

(52) **U.S. Cl.**

CPC **H01L 27/11582** (2013.01); **H01L 27/1157**
(2013.01); **H01L 27/11565** (2013.01)

(58) **Field of Classification Search**

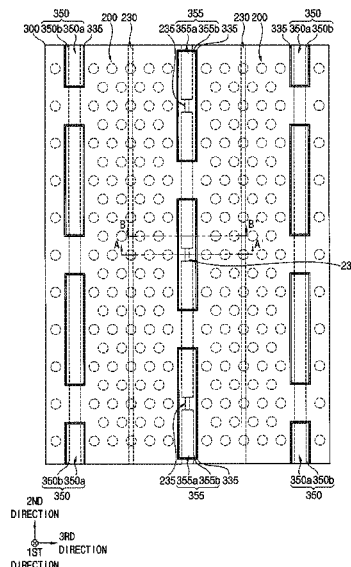
CPC H02L 37/22504; H02L 37/11519; H02L
37/11565; H02L 37/11587

See application file for complete search history.

(57) **ABSTRACT**

A vertical memory device includes gate electrode structures, channels, first to third division patterns, and a first support layer. The gate electrode structure includes gate electrodes stacked in a first direction, and extends in a second direction. The gate electrode structures are spaced apart from one another in a third direction. The first division pattern extends in the second direction between the gate electrode structures. The second and third division patterns are alternately disposed in the second direction between the gate electrode structures. The first support layer is on the gate electrode structures at substantially the same height as upper portions of the first and second division patterns, and contacts the upper portions of the first and second division patterns. The upper portions of the first and second division patterns are arranged in a zigzag pattern in the second direction in a plan view.

18 Claims, 31 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

10,566,346	B2 *	2/2020	Lee	H01L 21/28568
11,049,871	B2 *	6/2021	Ohnuki	H01L 27/11565
11,069,698	B2 *	7/2021	Kim	H01L 27/11575
2014/0239375	A1	8/2014	Kim et al.	
2014/0264549	A1	9/2014	Lee	
2015/0372101	A1 *	12/2015	Lee	H01L 27/11519
				257/314
2016/0064407	A1 *	3/2016	Kim	H01L 27/11565
				257/324
2018/0374862	A1 *	12/2018	Lee	H01L 27/11529
2019/0043883	A1 *	2/2019	Xu	H01L 23/528
2019/0181226	A1 *	6/2019	Choi	H01L 27/11573
2021/0320125	A1 *	10/2021	Shin	H01L 23/5226

* cited by examiner

FIG. 1

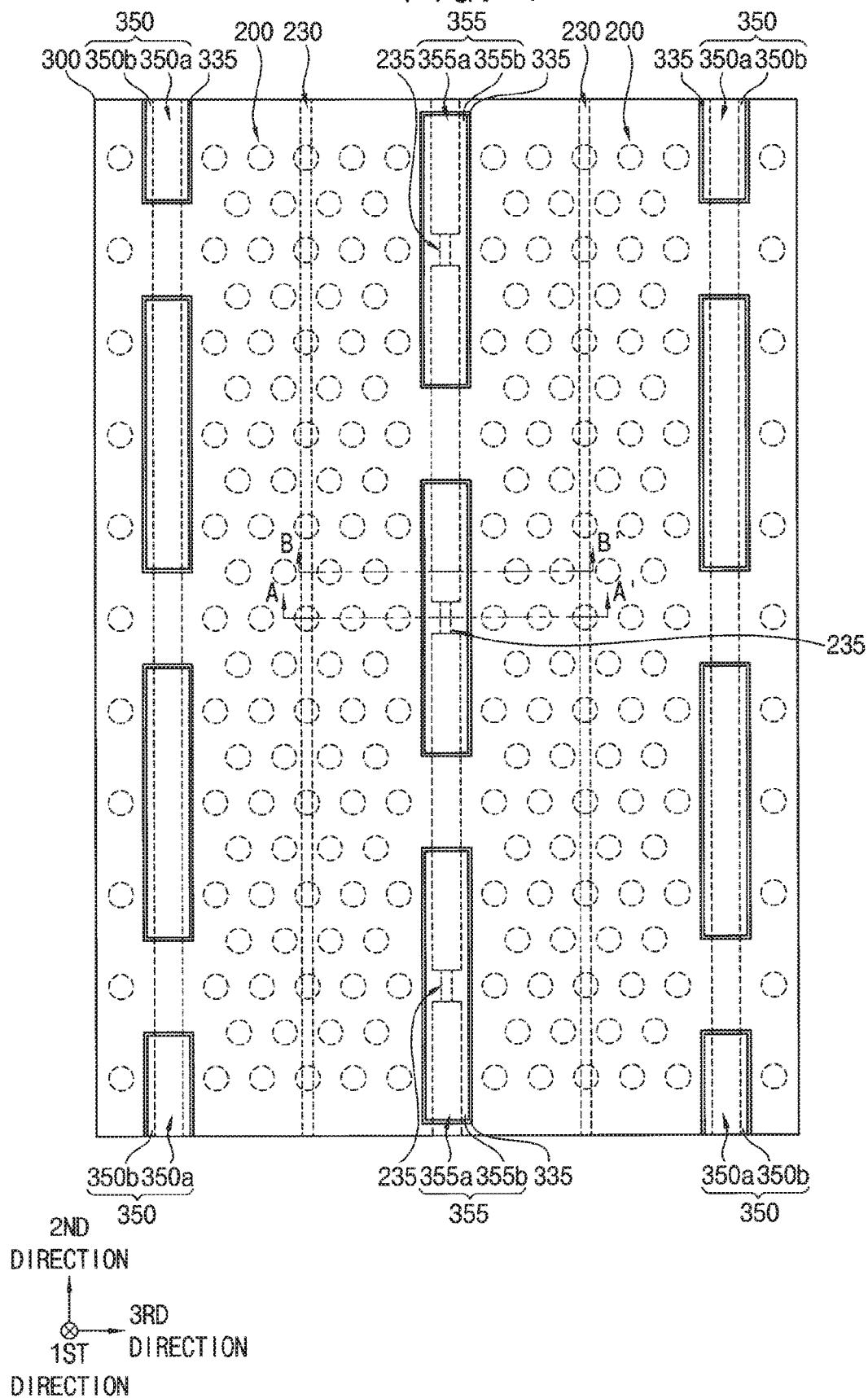
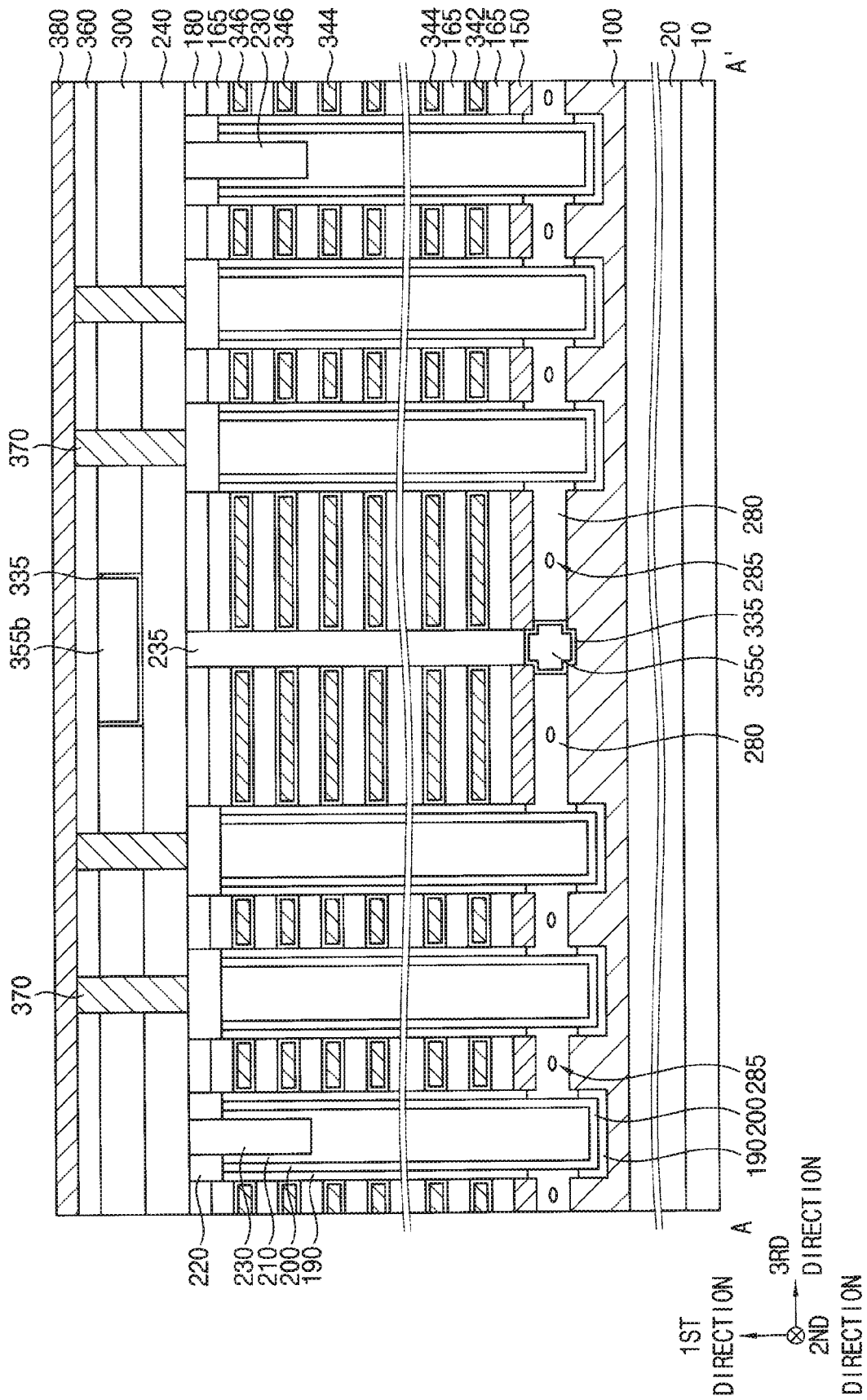
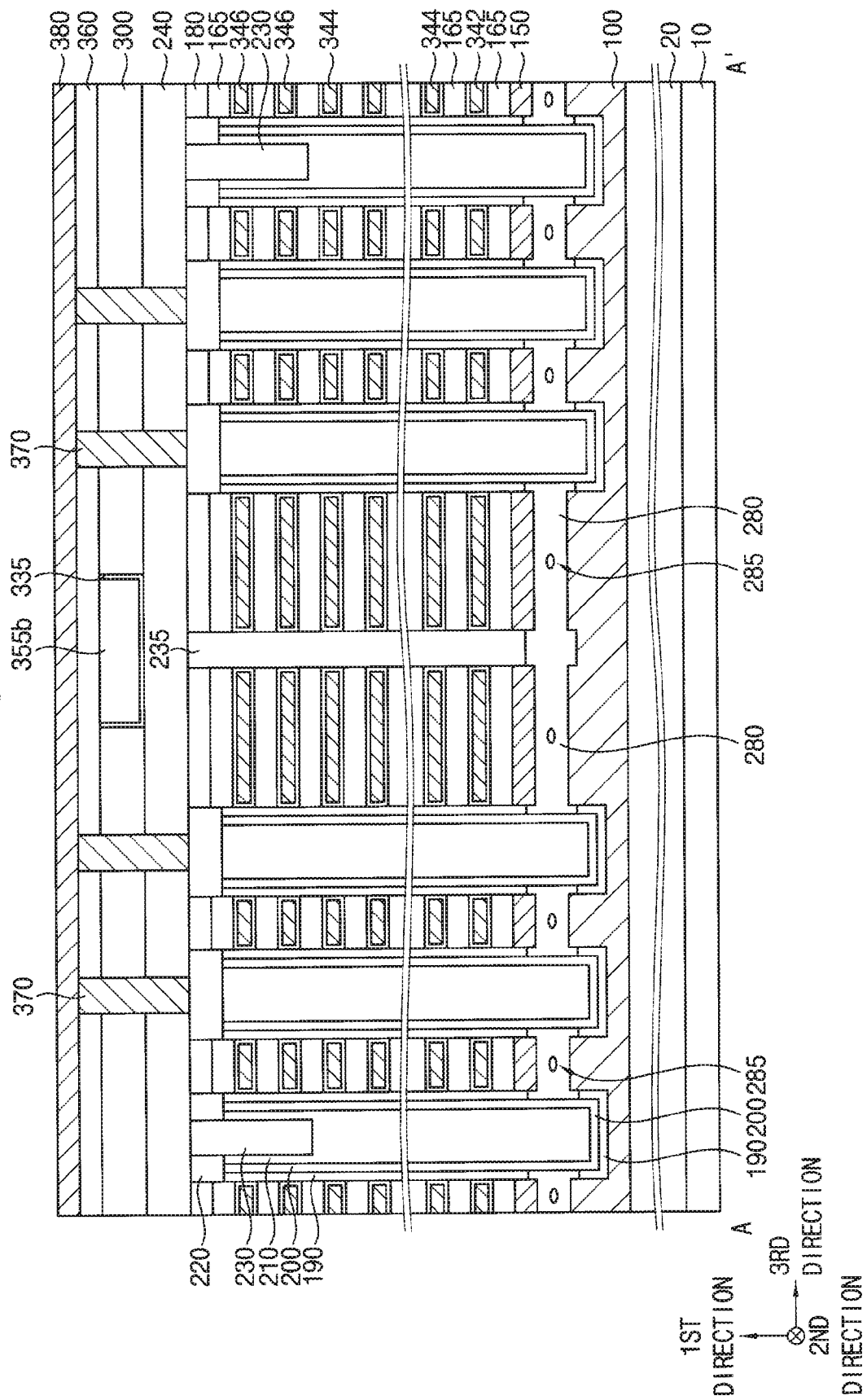


FIG. 2A



25
G
—
L



3
c
G
—
L

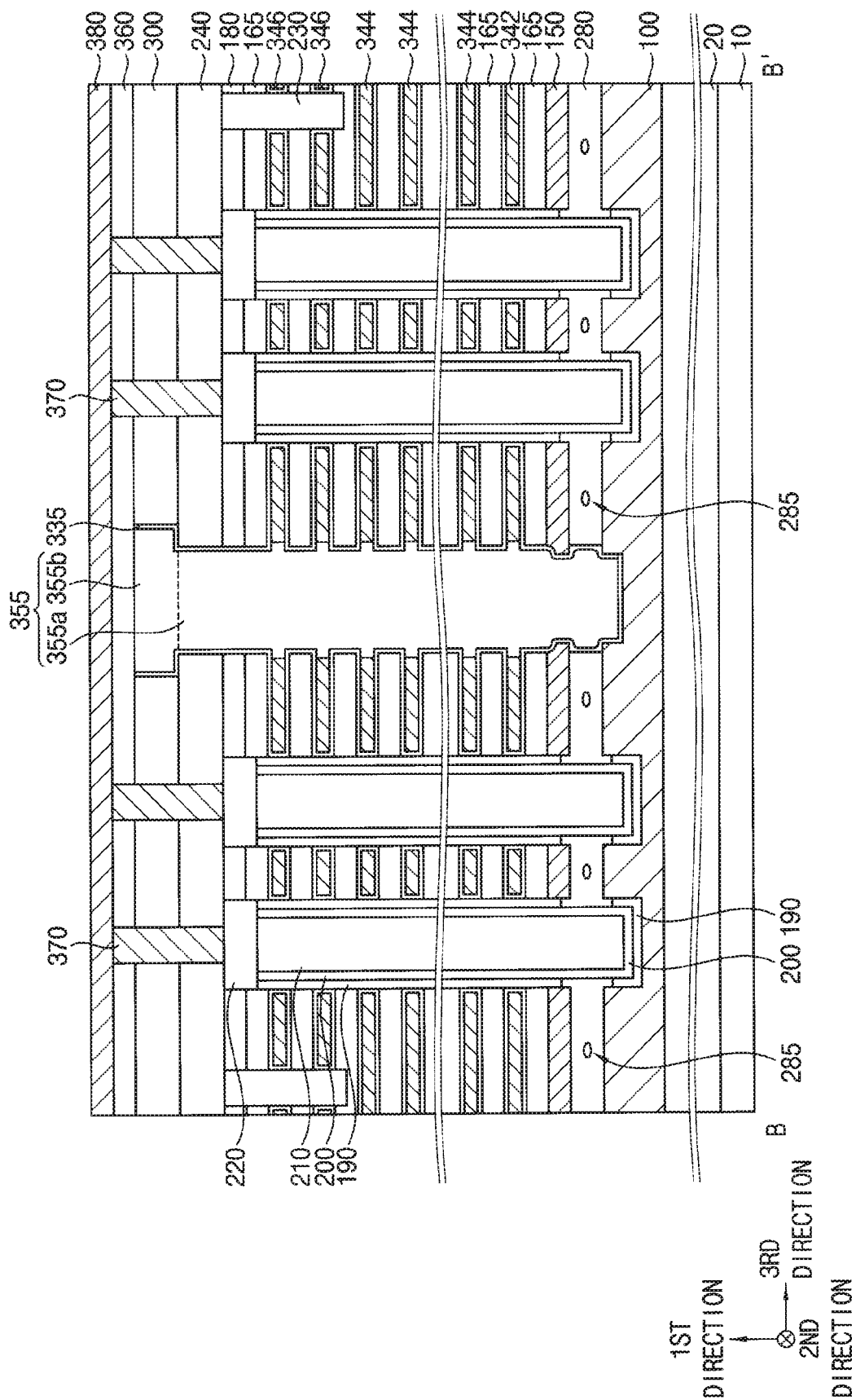


FIG. 4

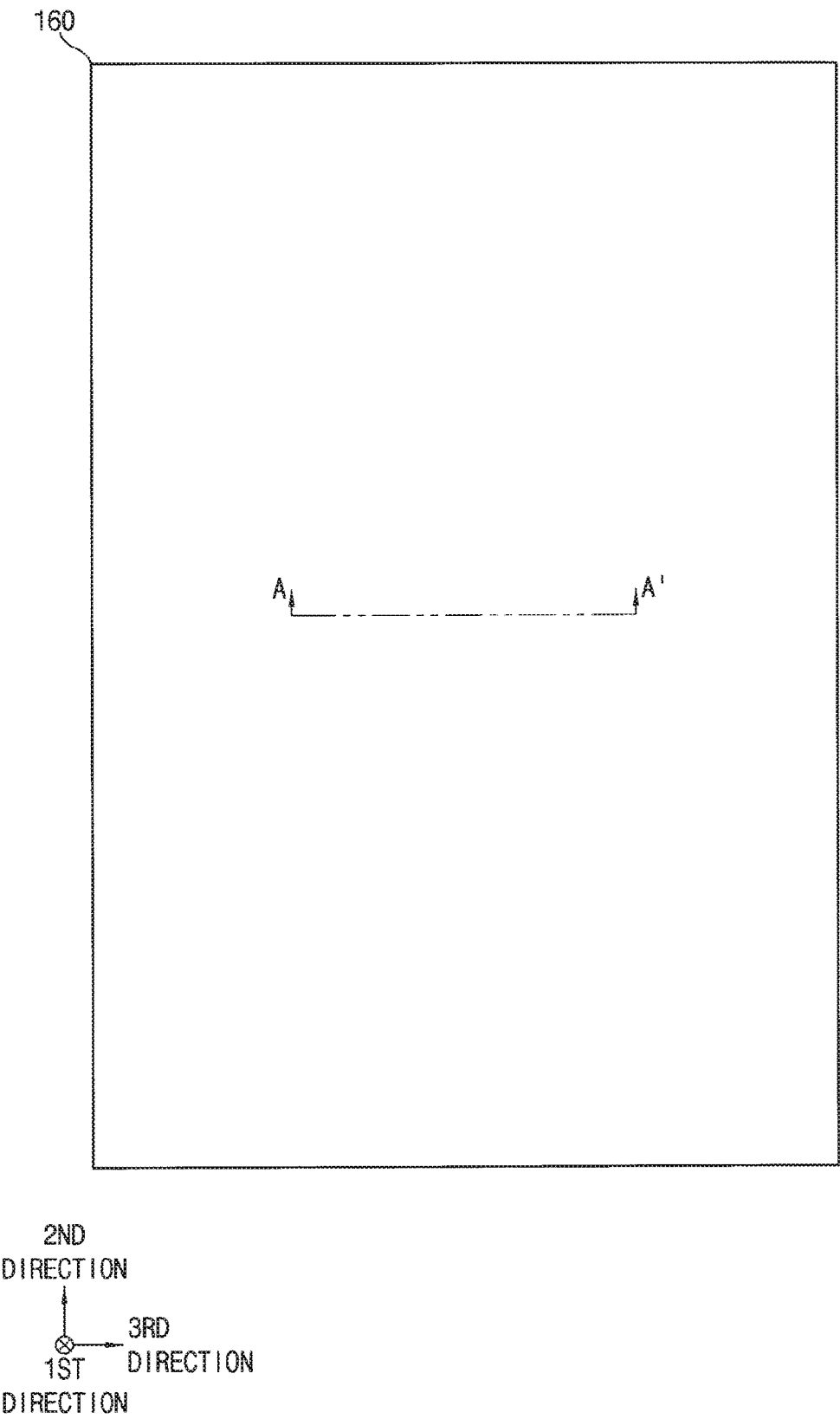


FIG. 5

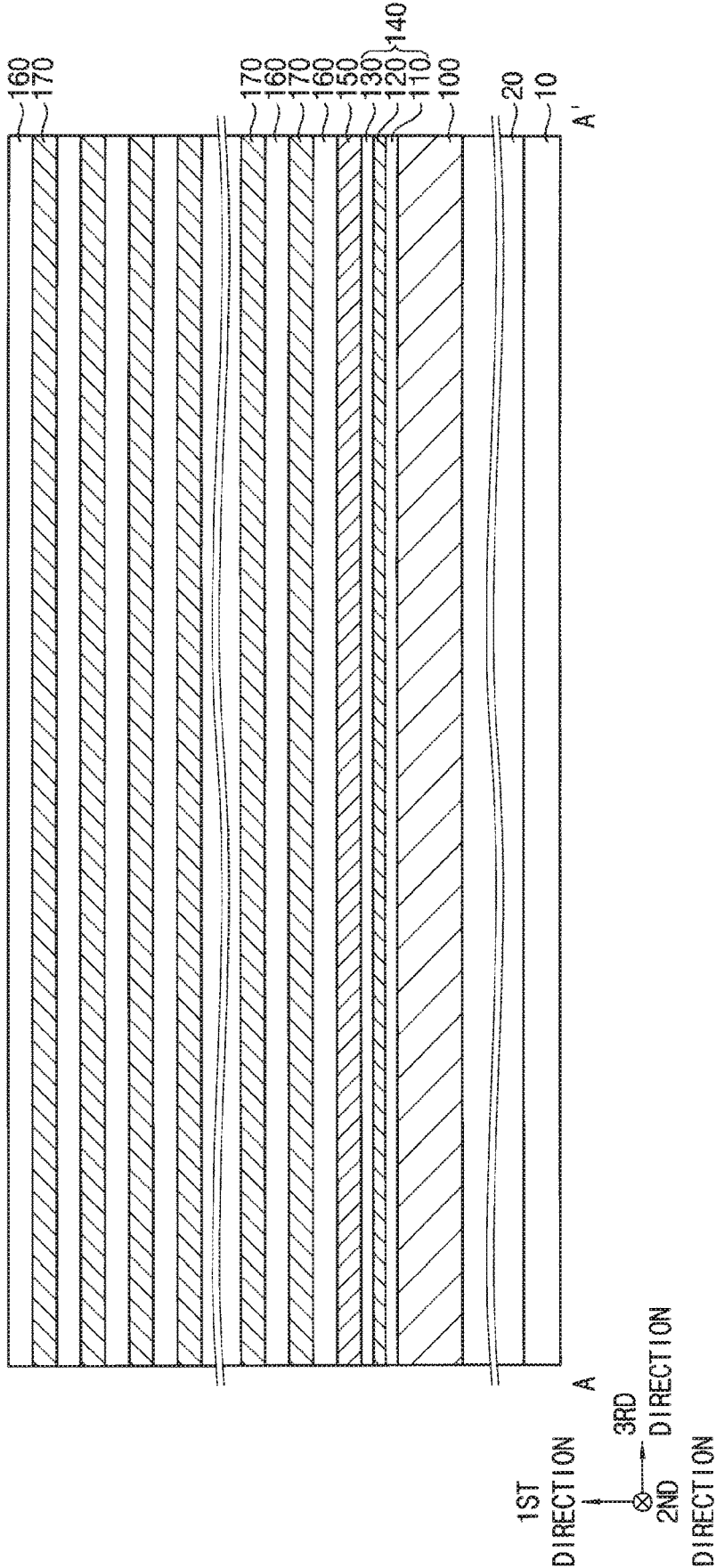


FIG. 6

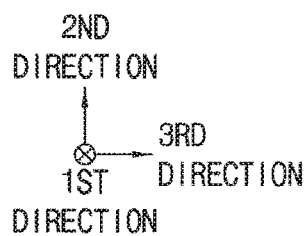
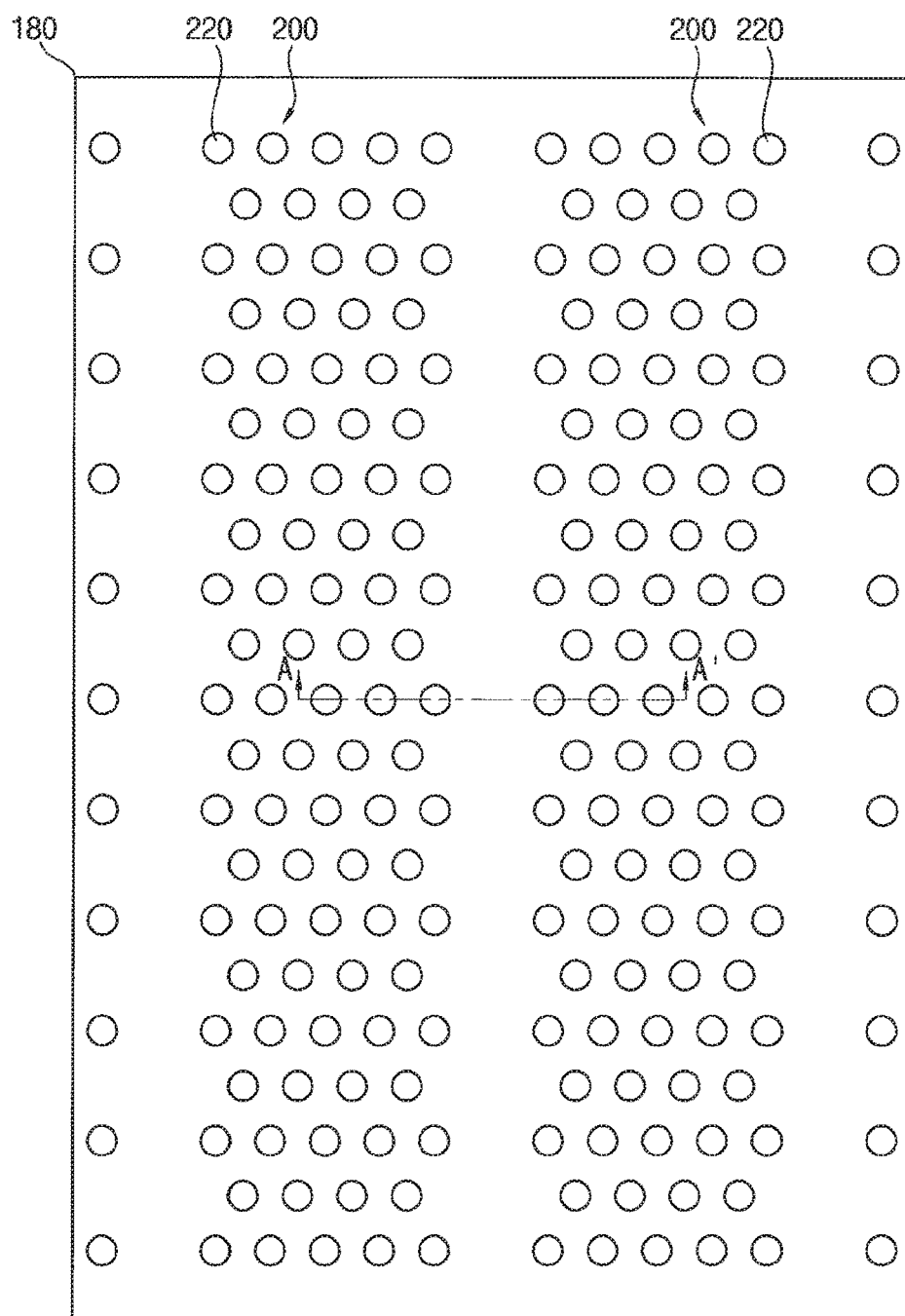


FIG. 7

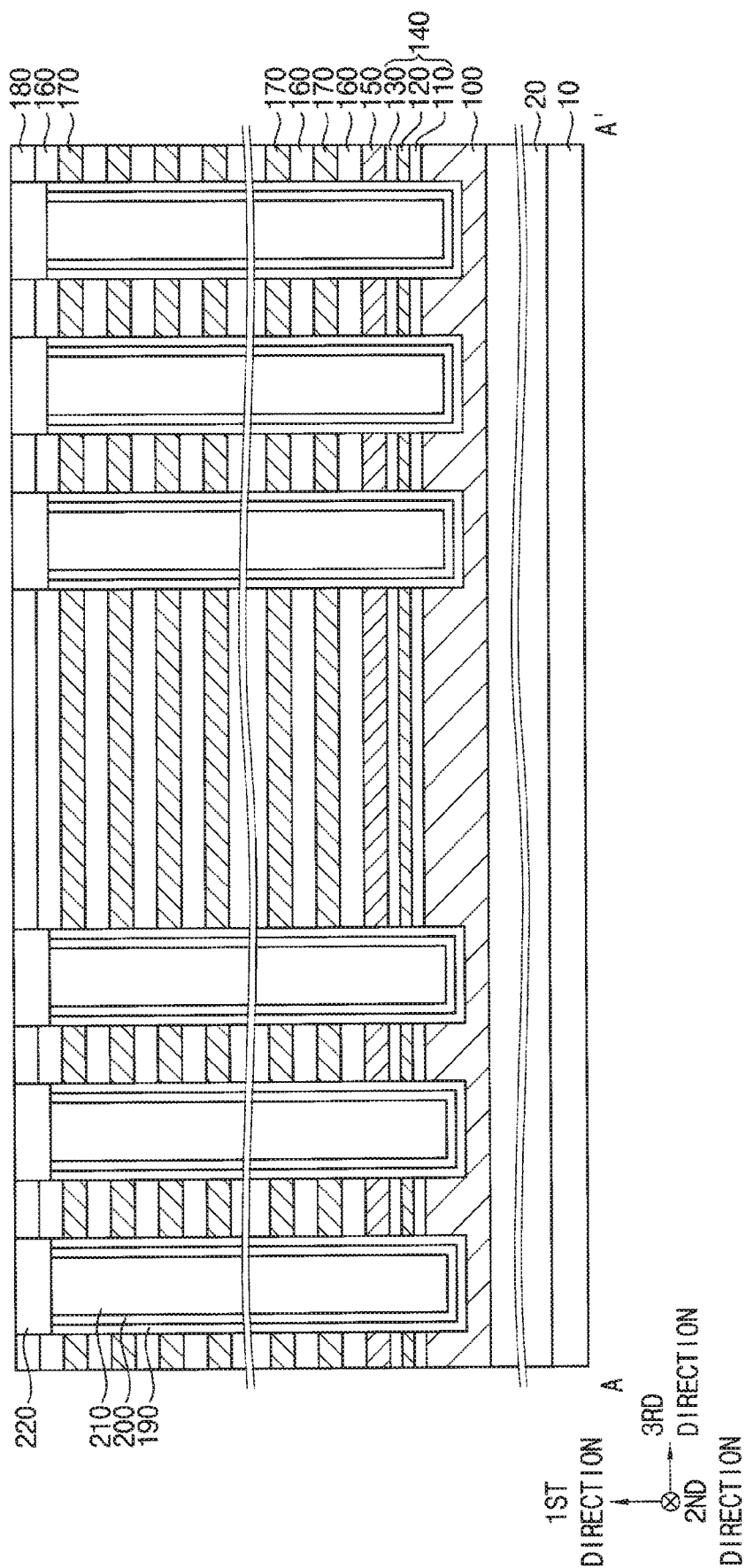


FIG. 8

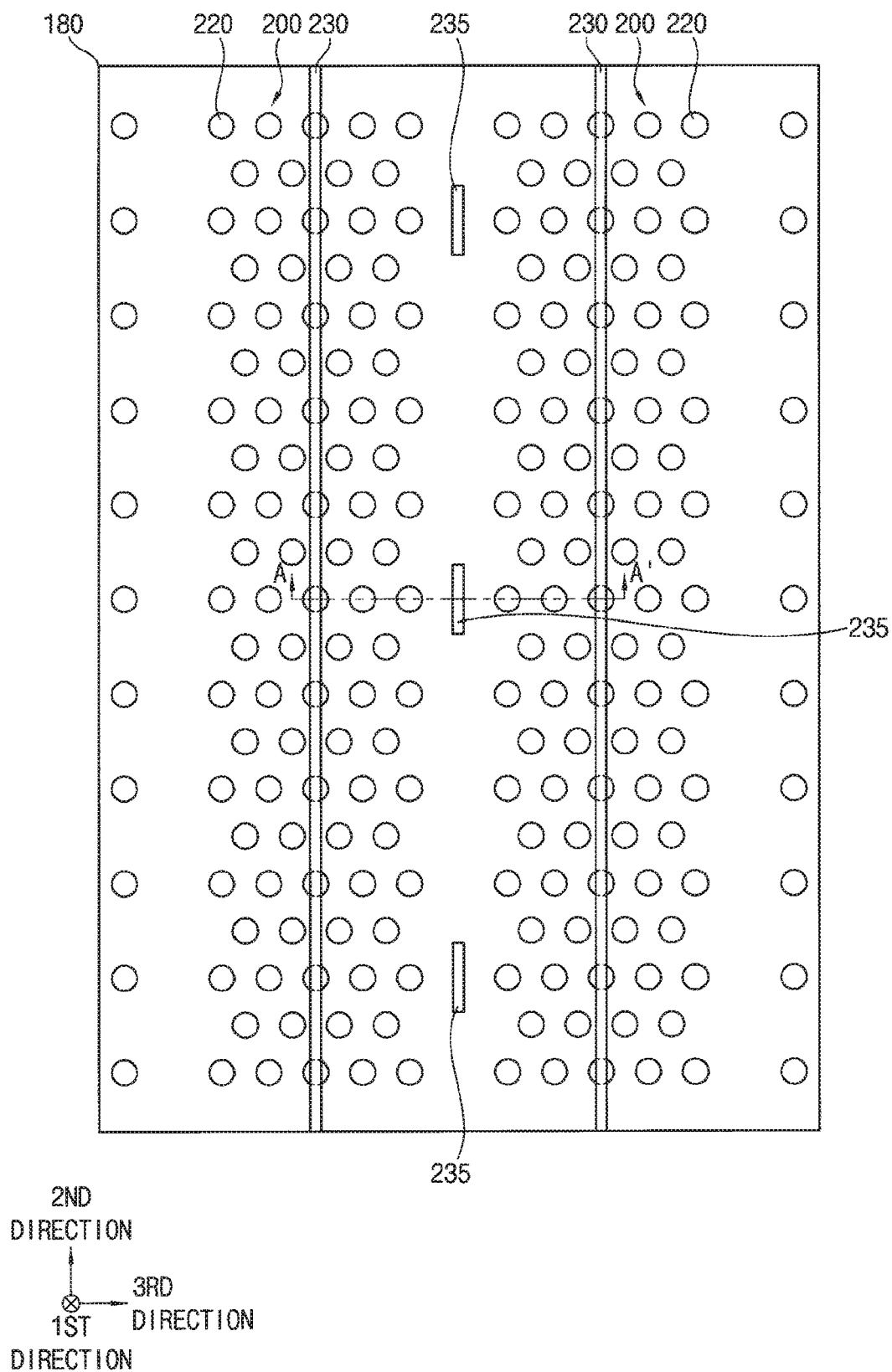


FIG. 9

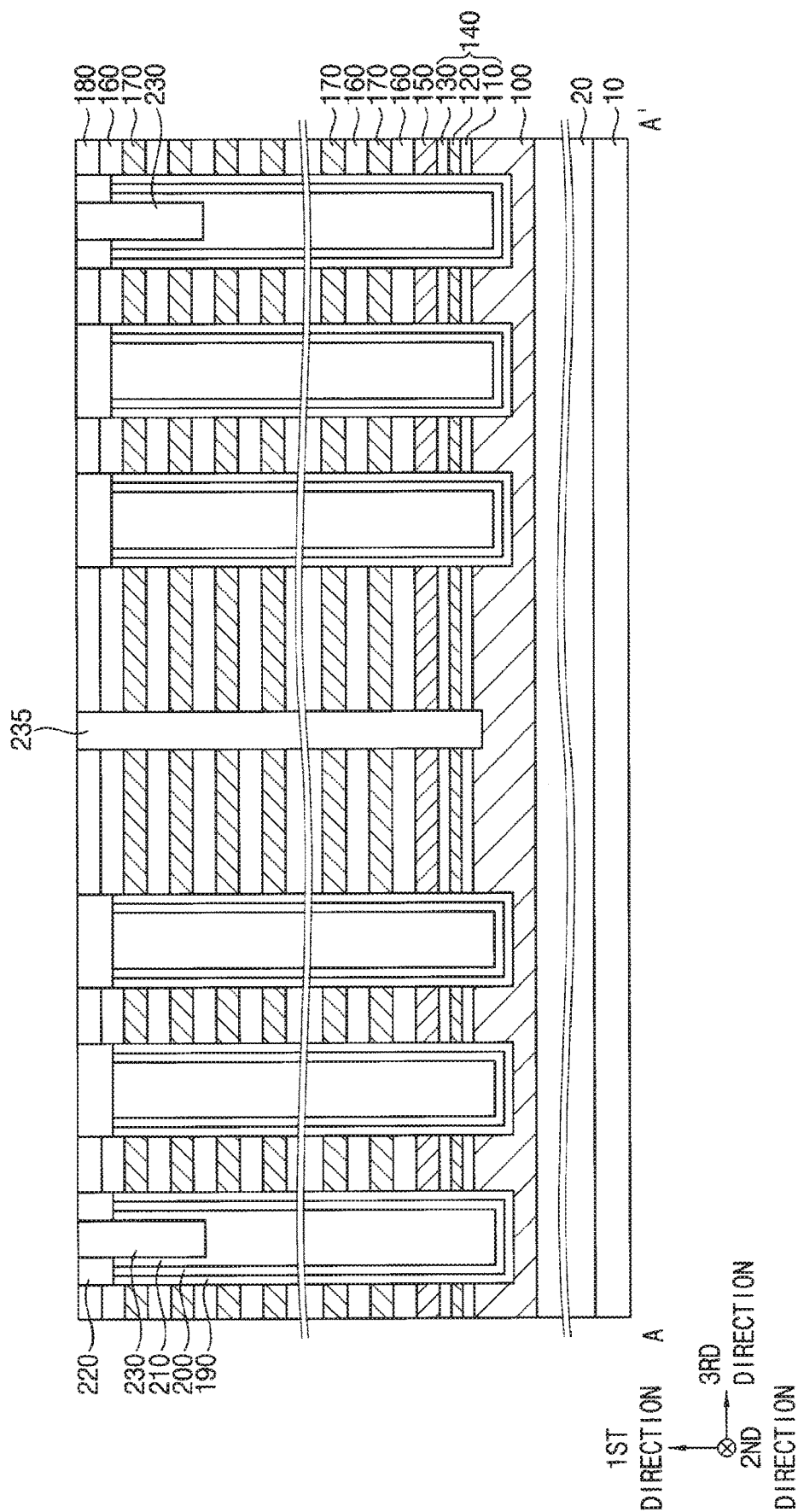


FIG. 10

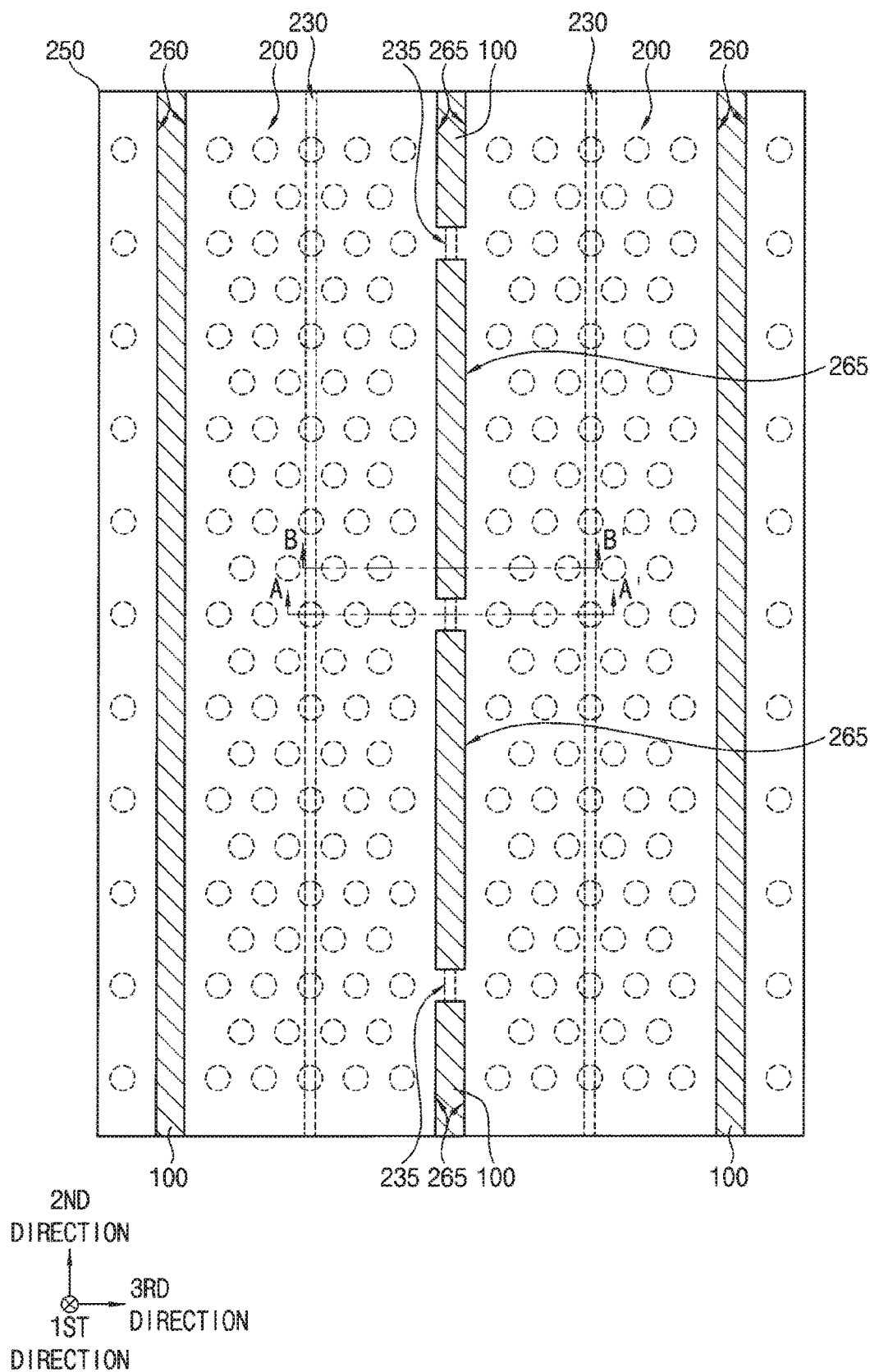


FIG. 11

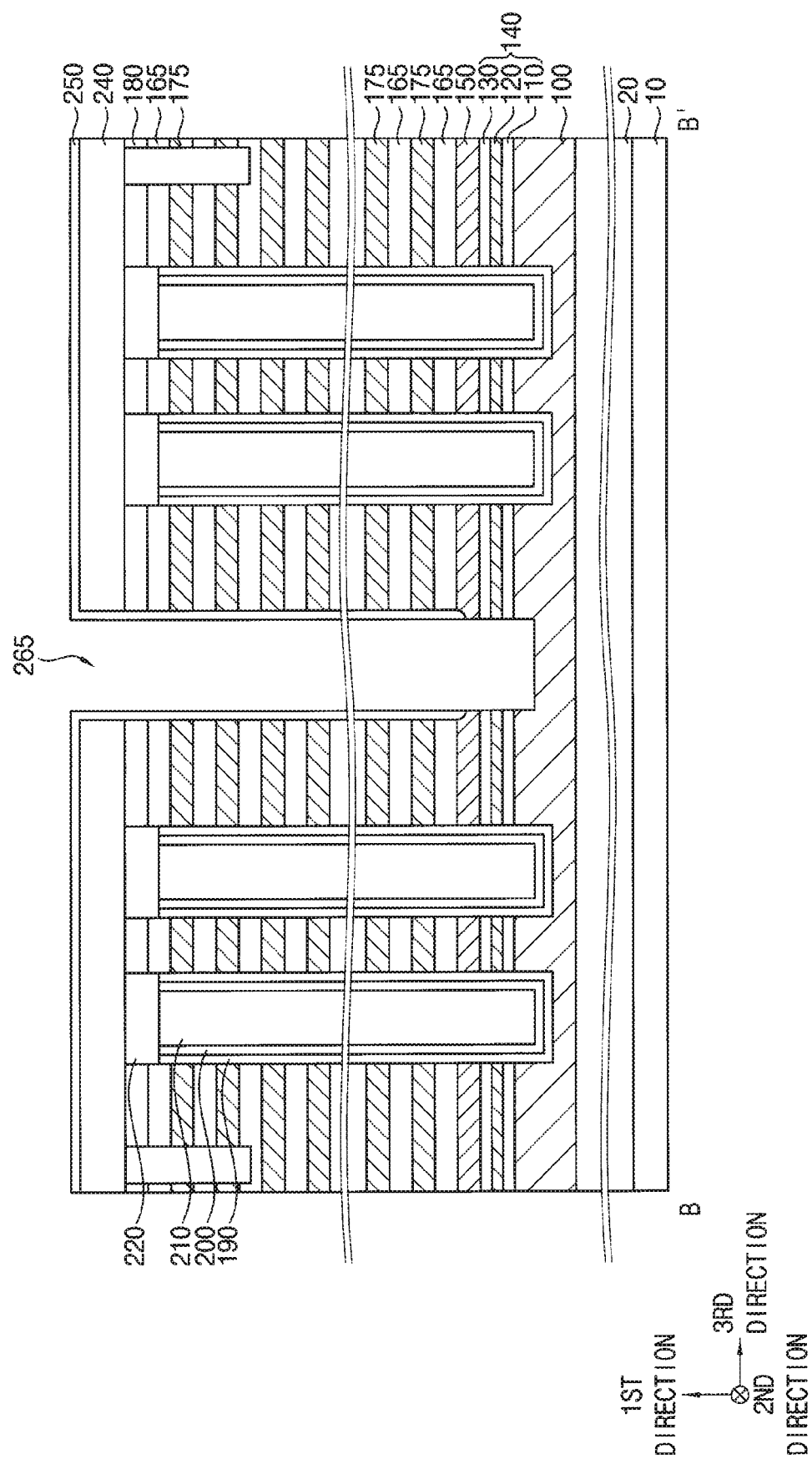
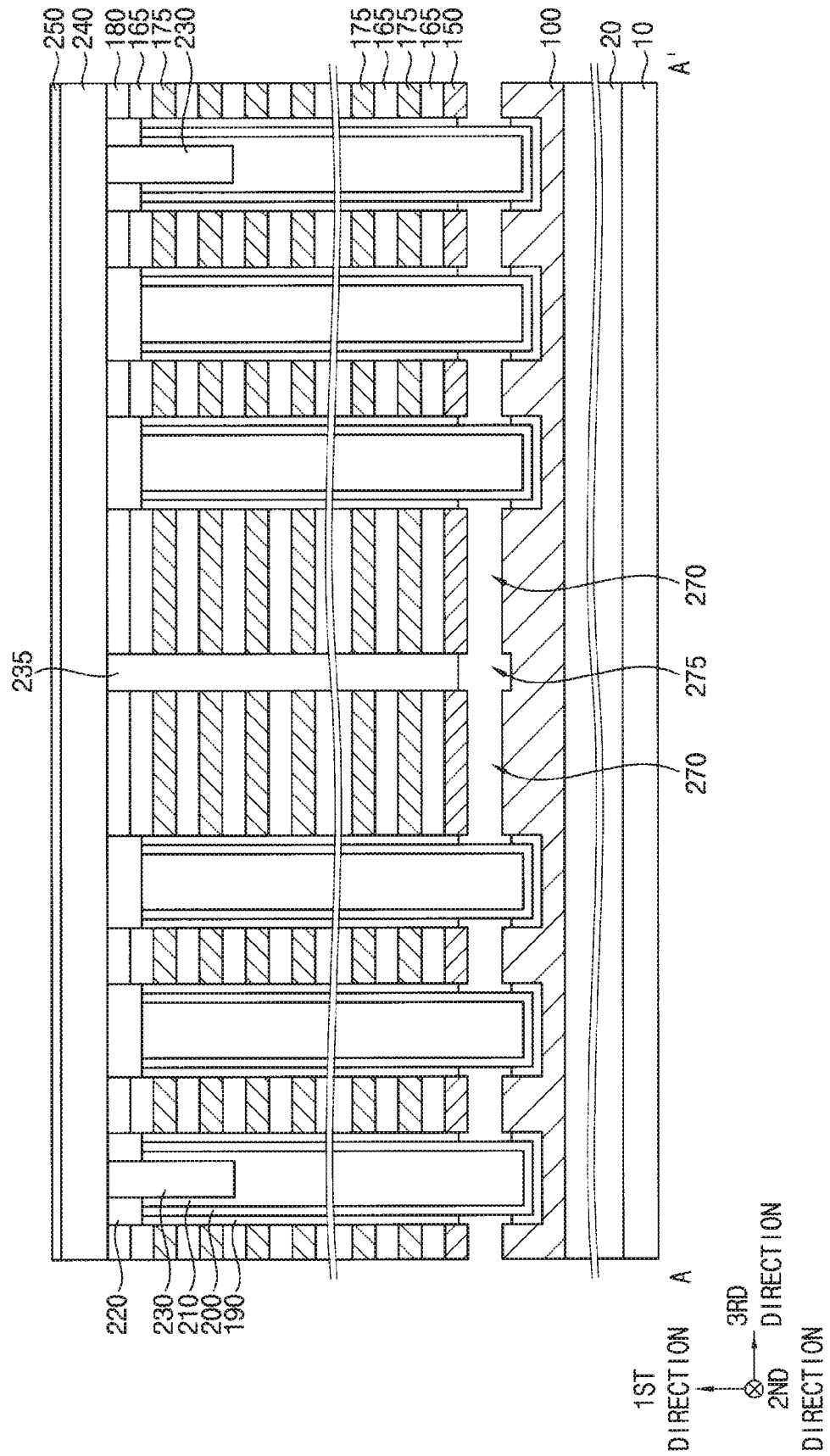


FIG. 12



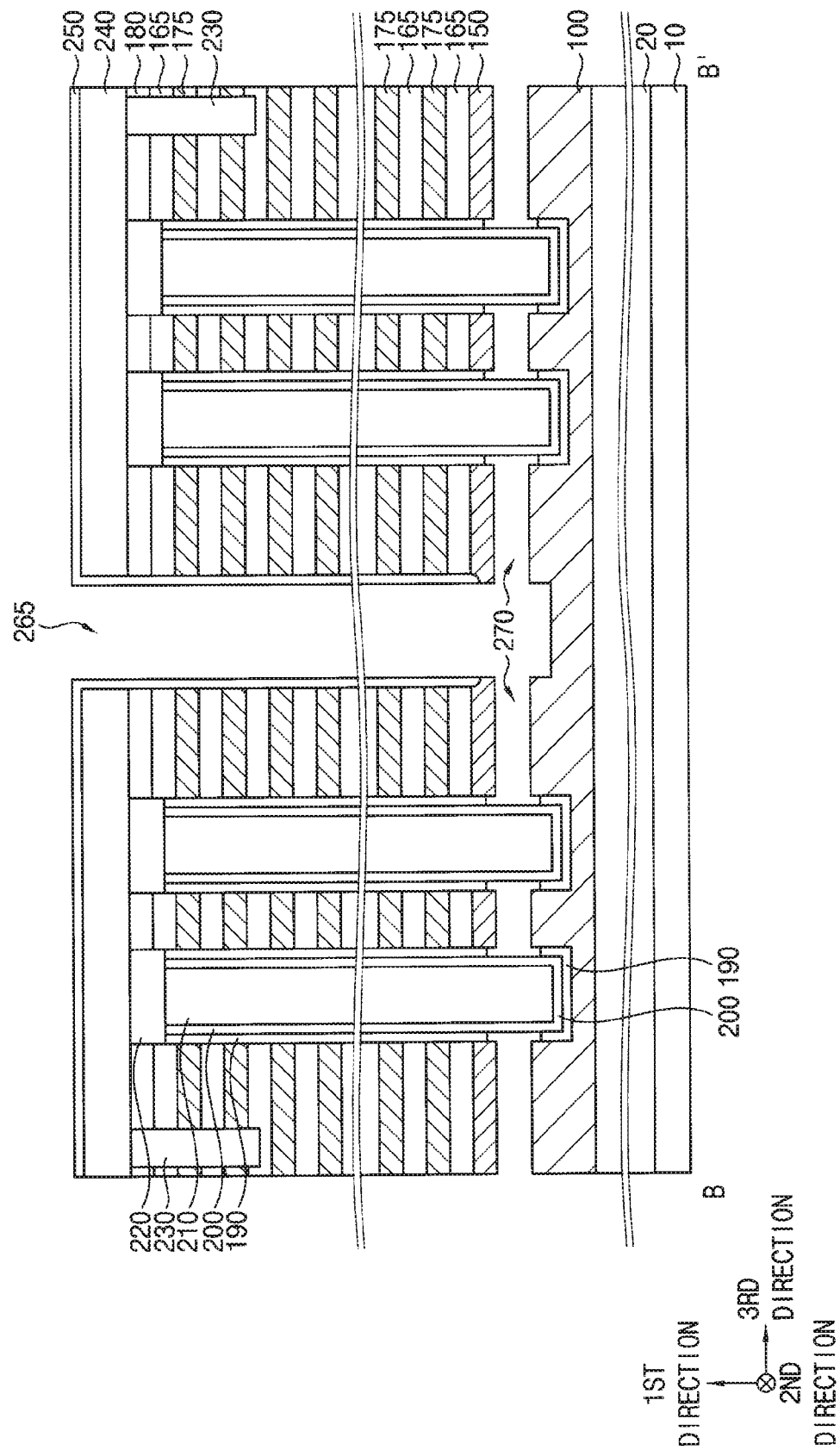


FIG. 14

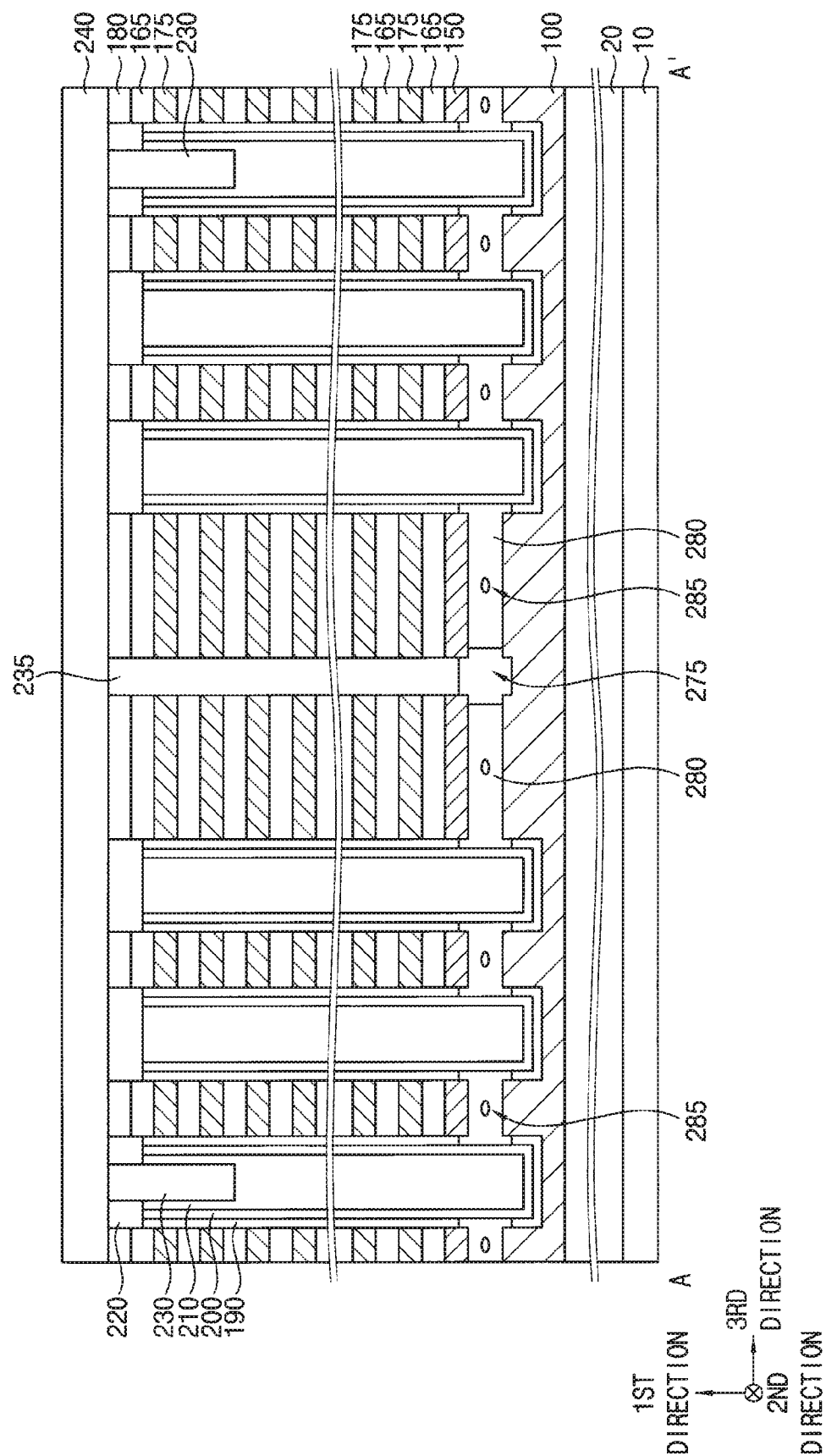


FIG. 15

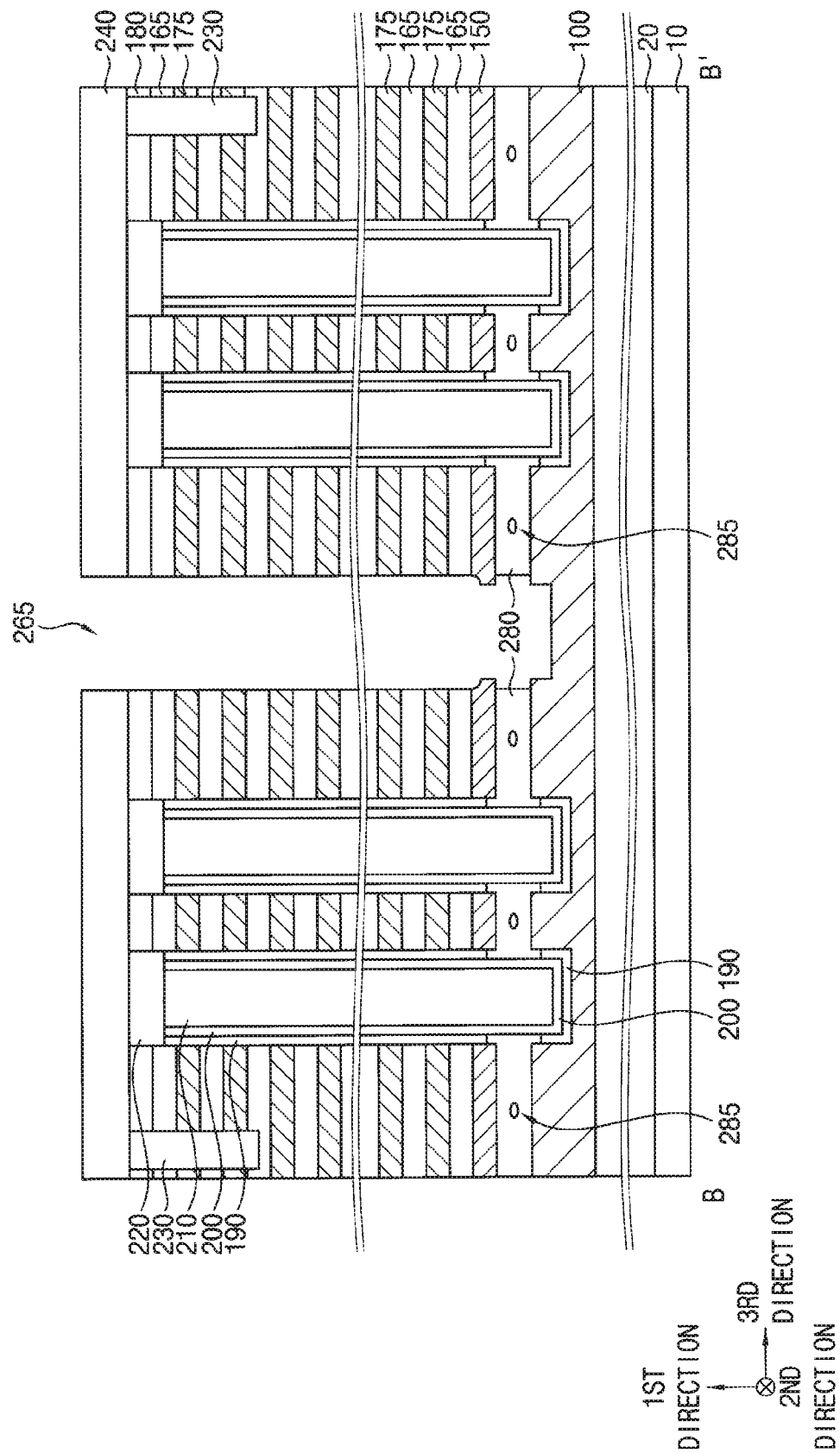


FIG. 16

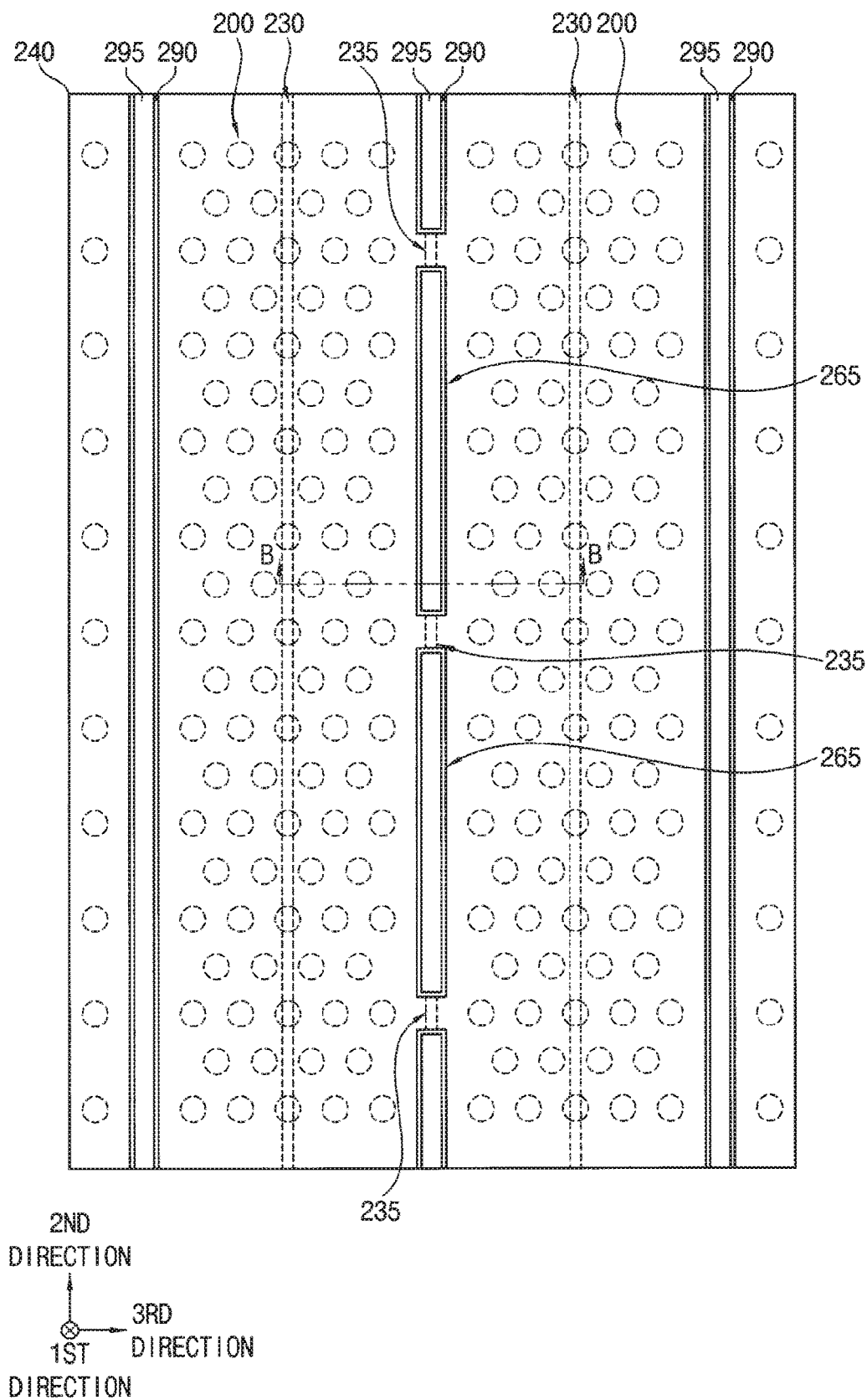


FIG. 17

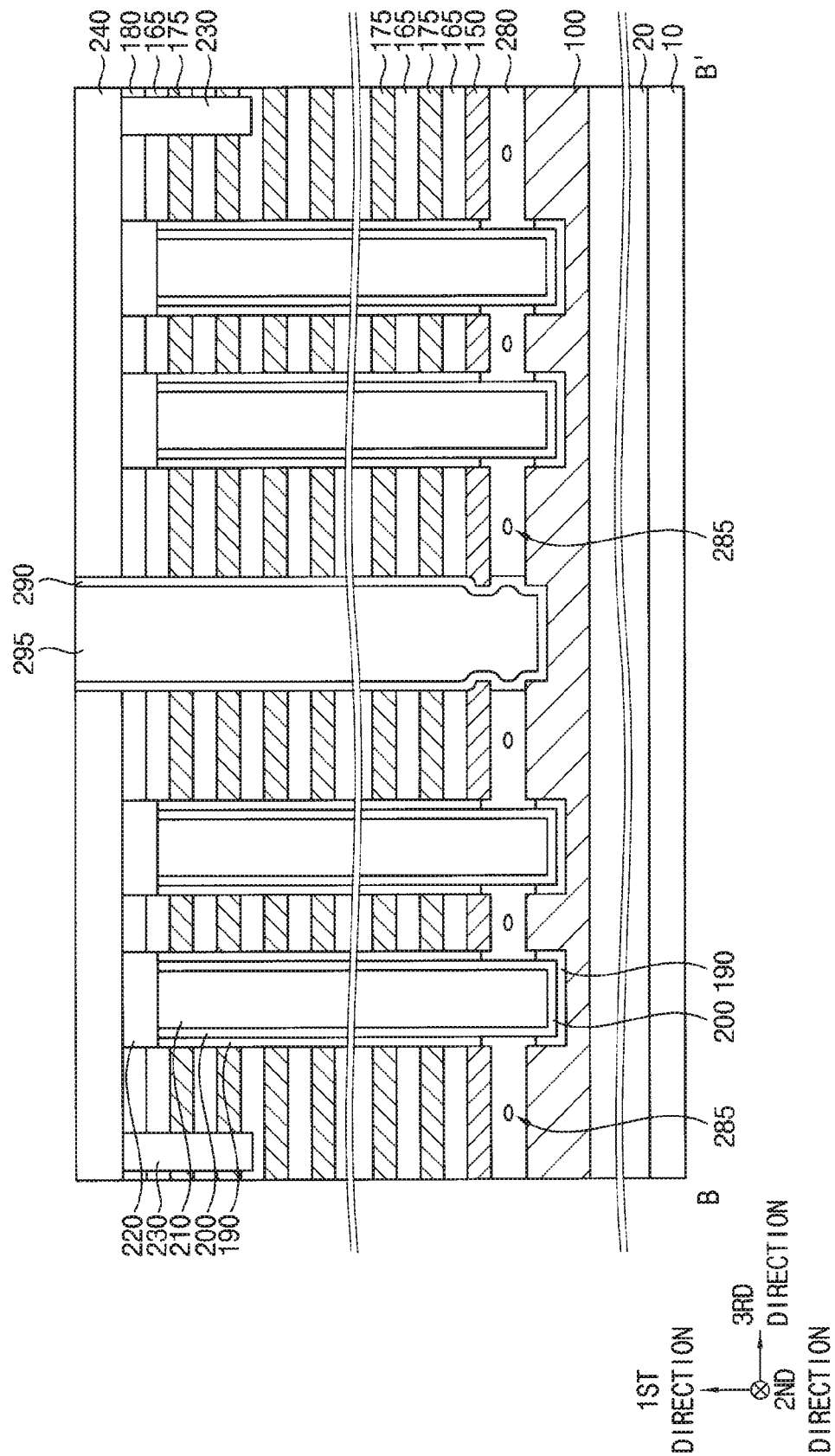


FIG. 18

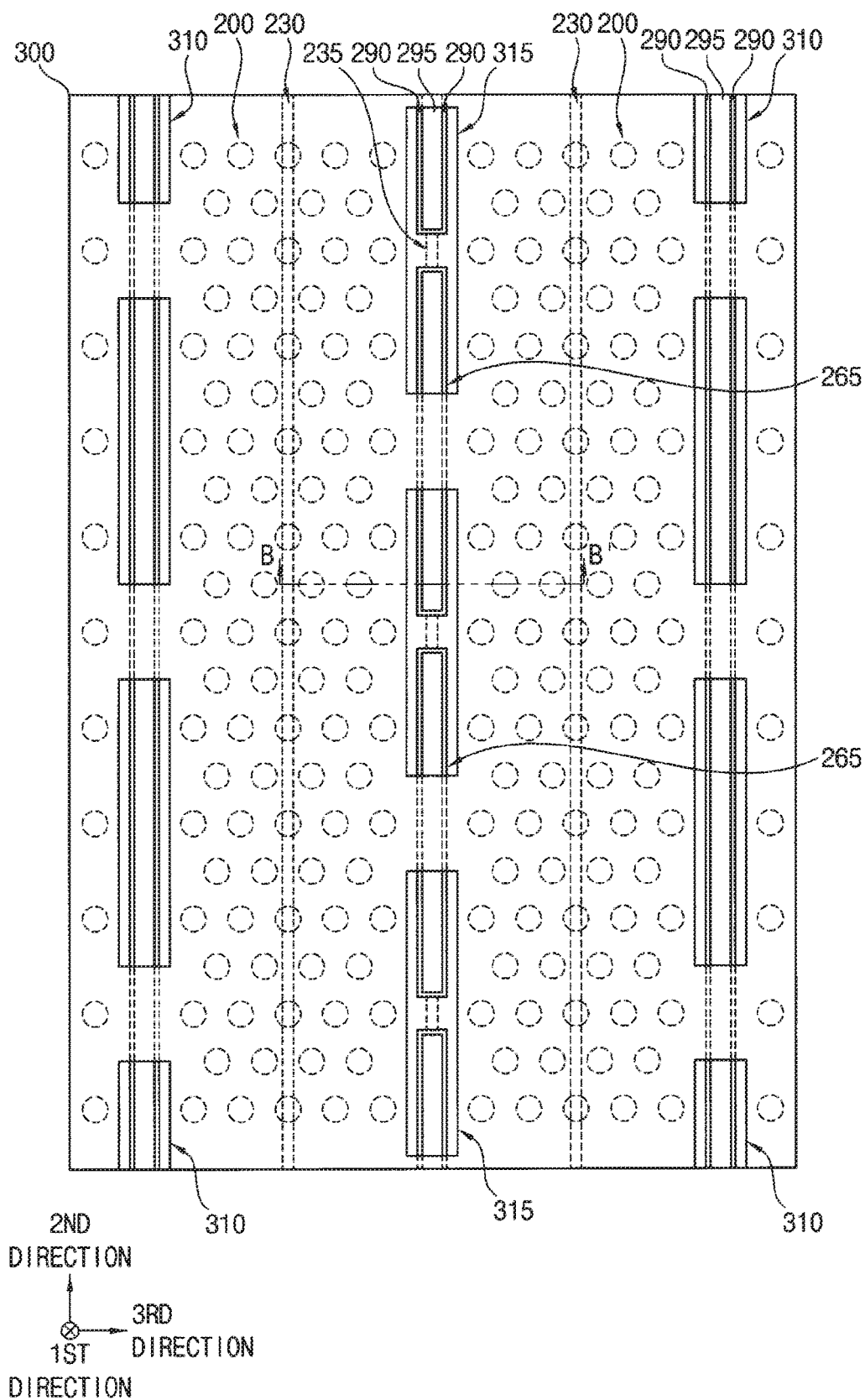


FIG. 19

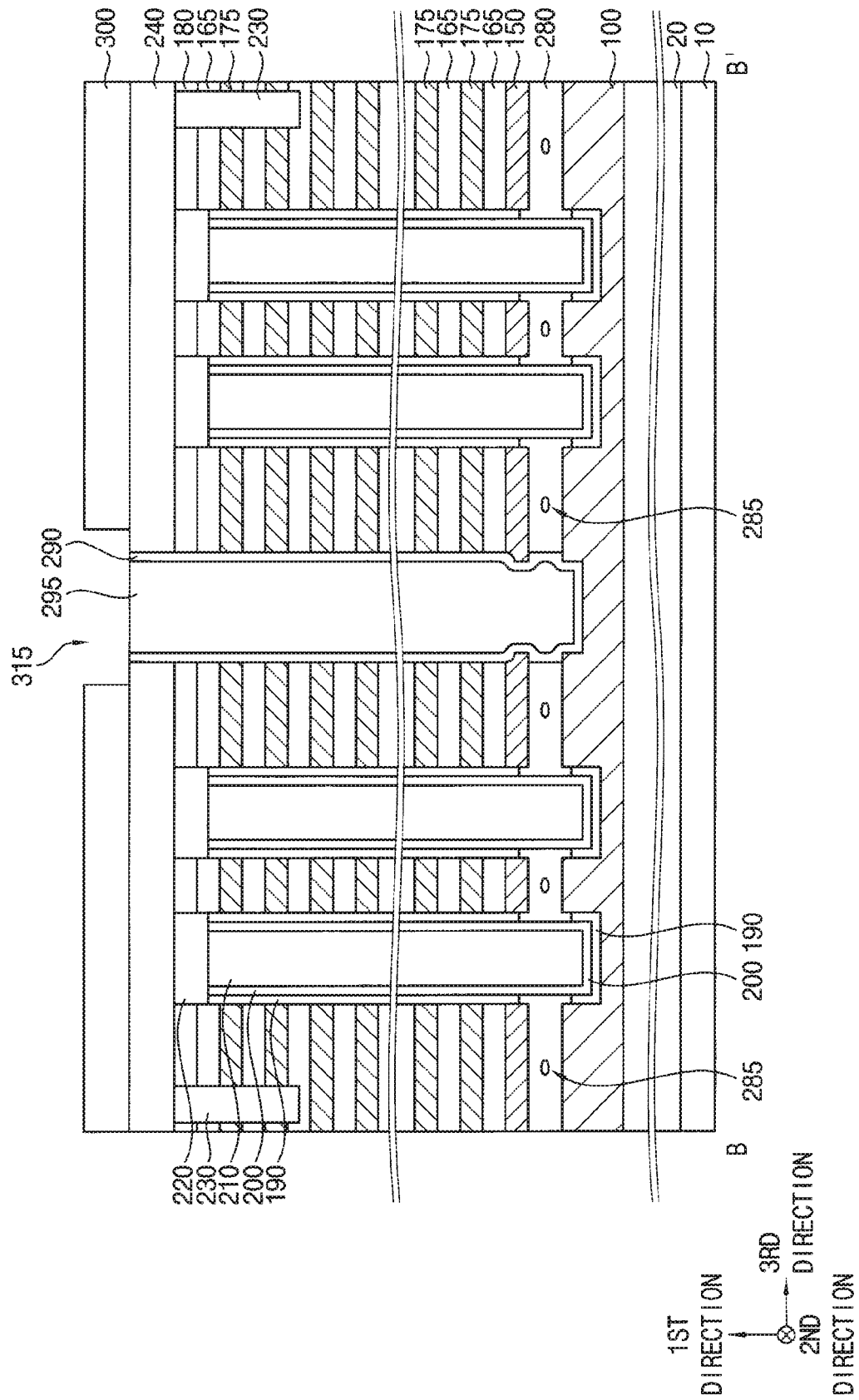


FIG. 20

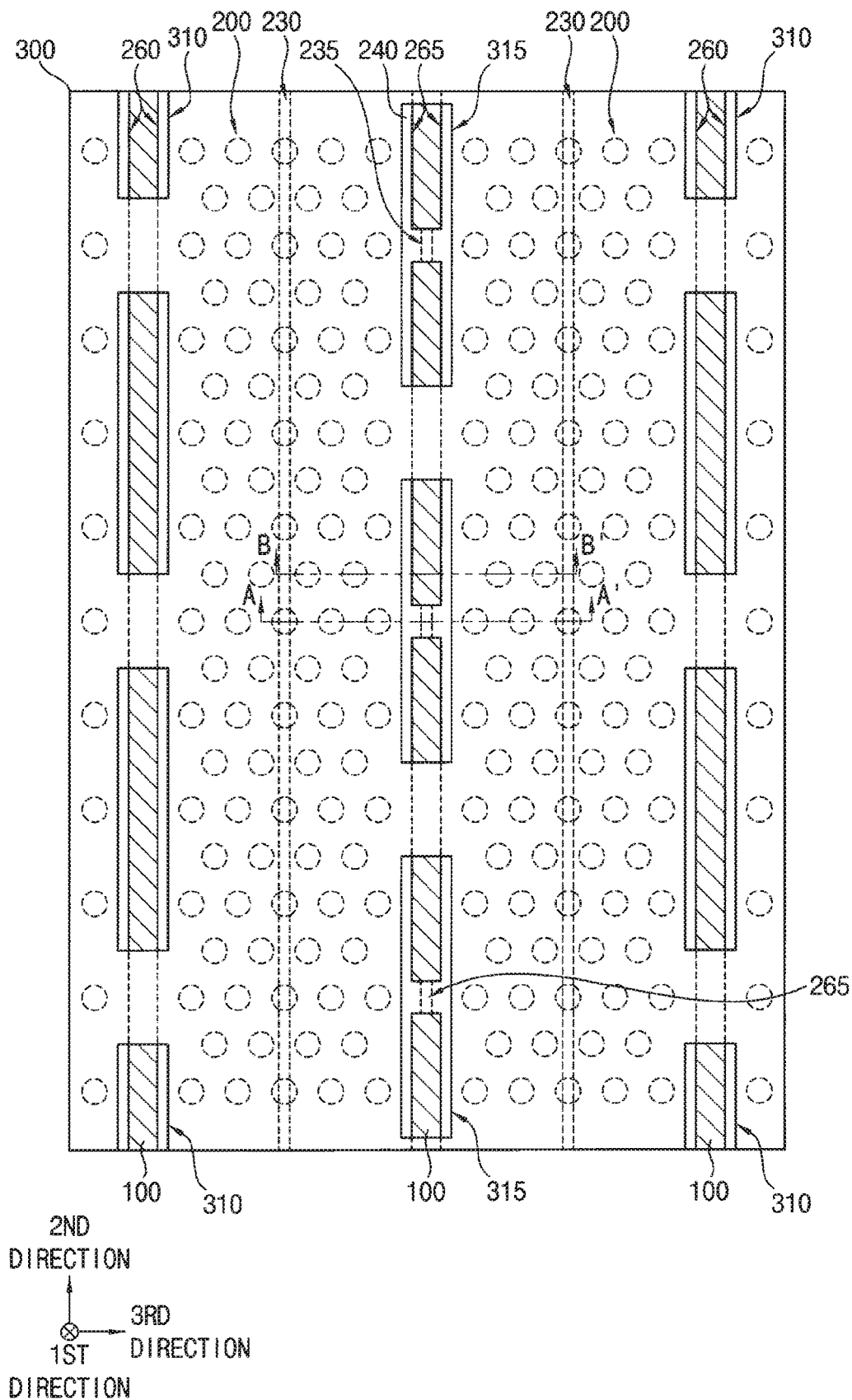


FIG. 21

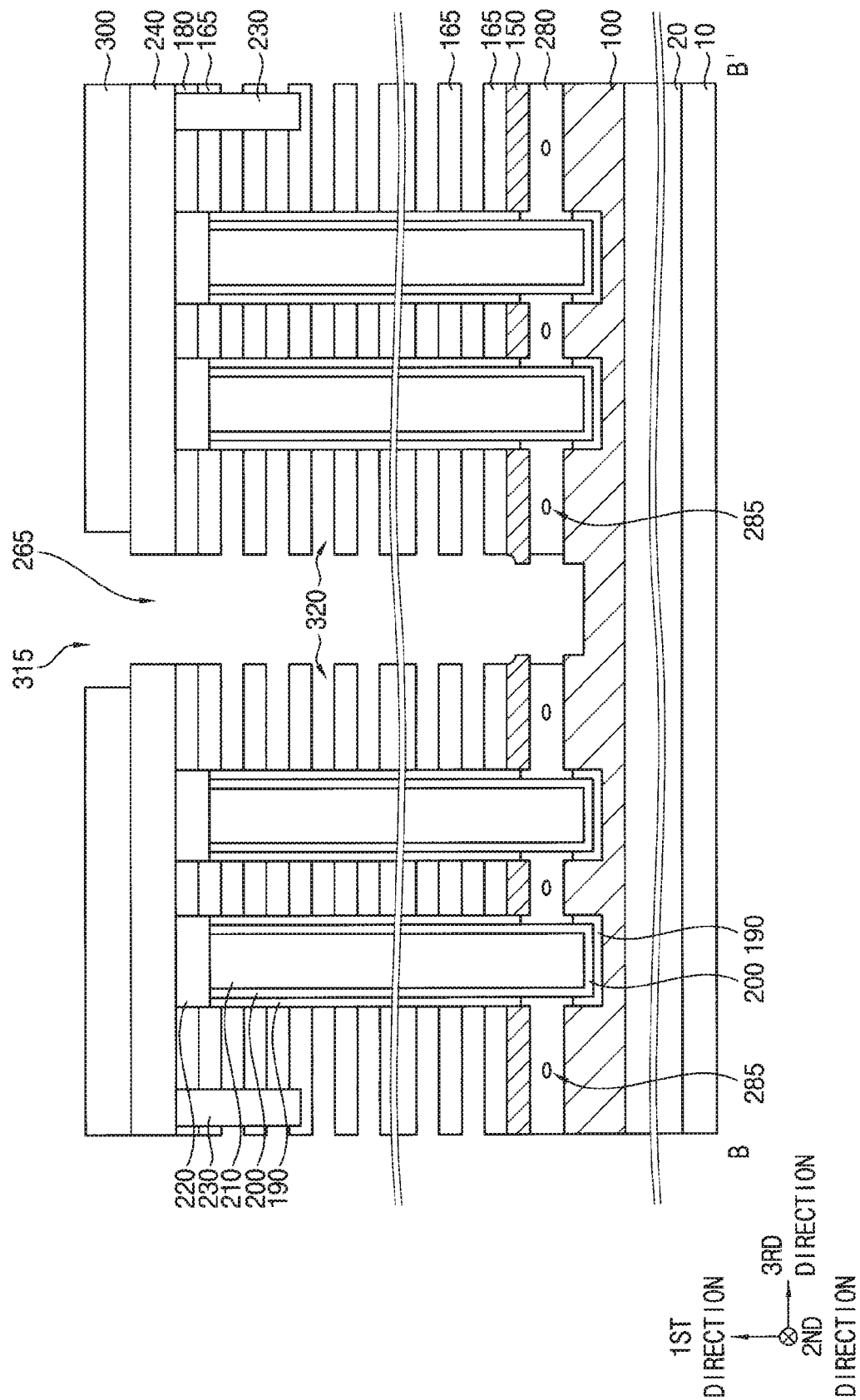


FIG. 22

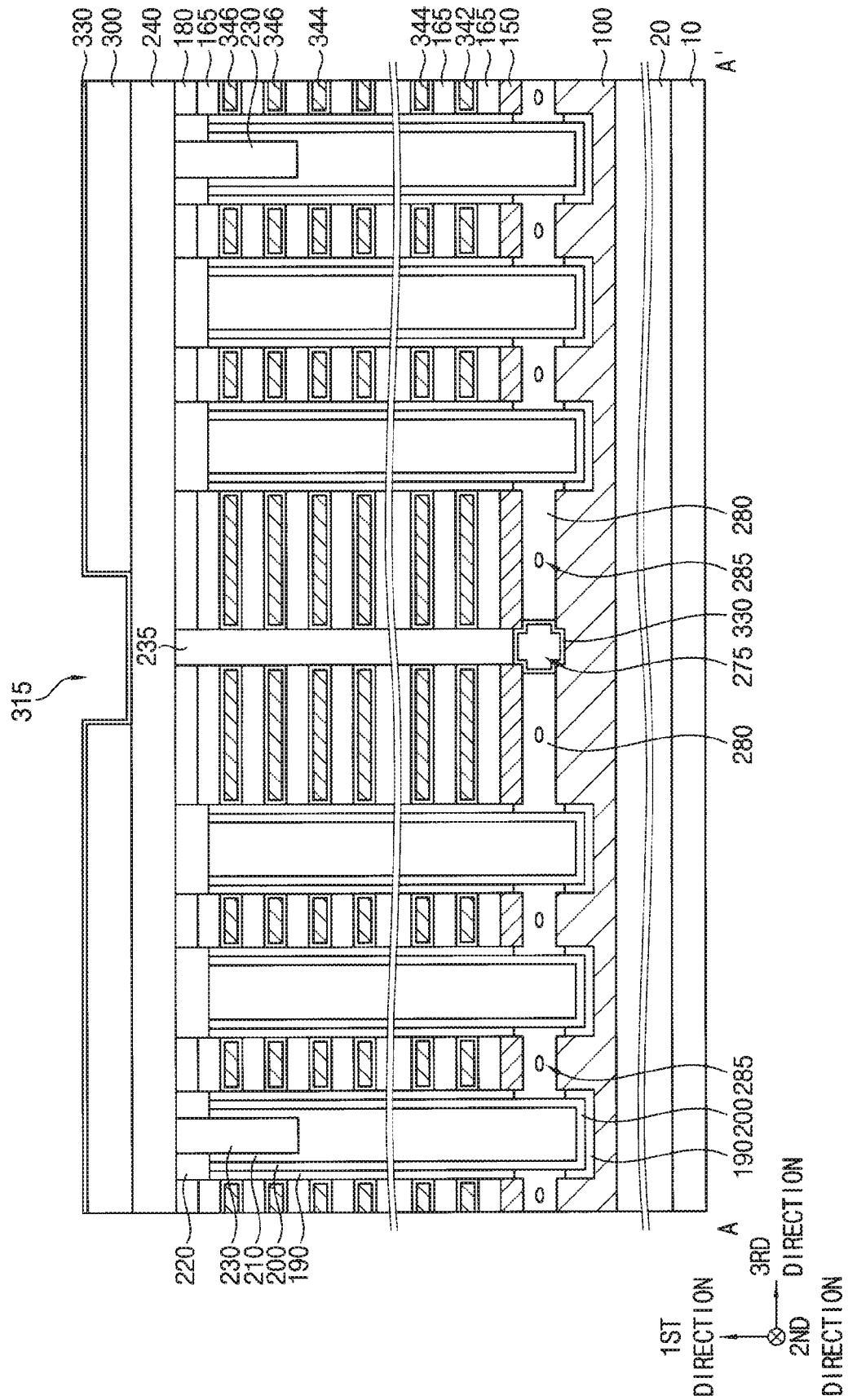
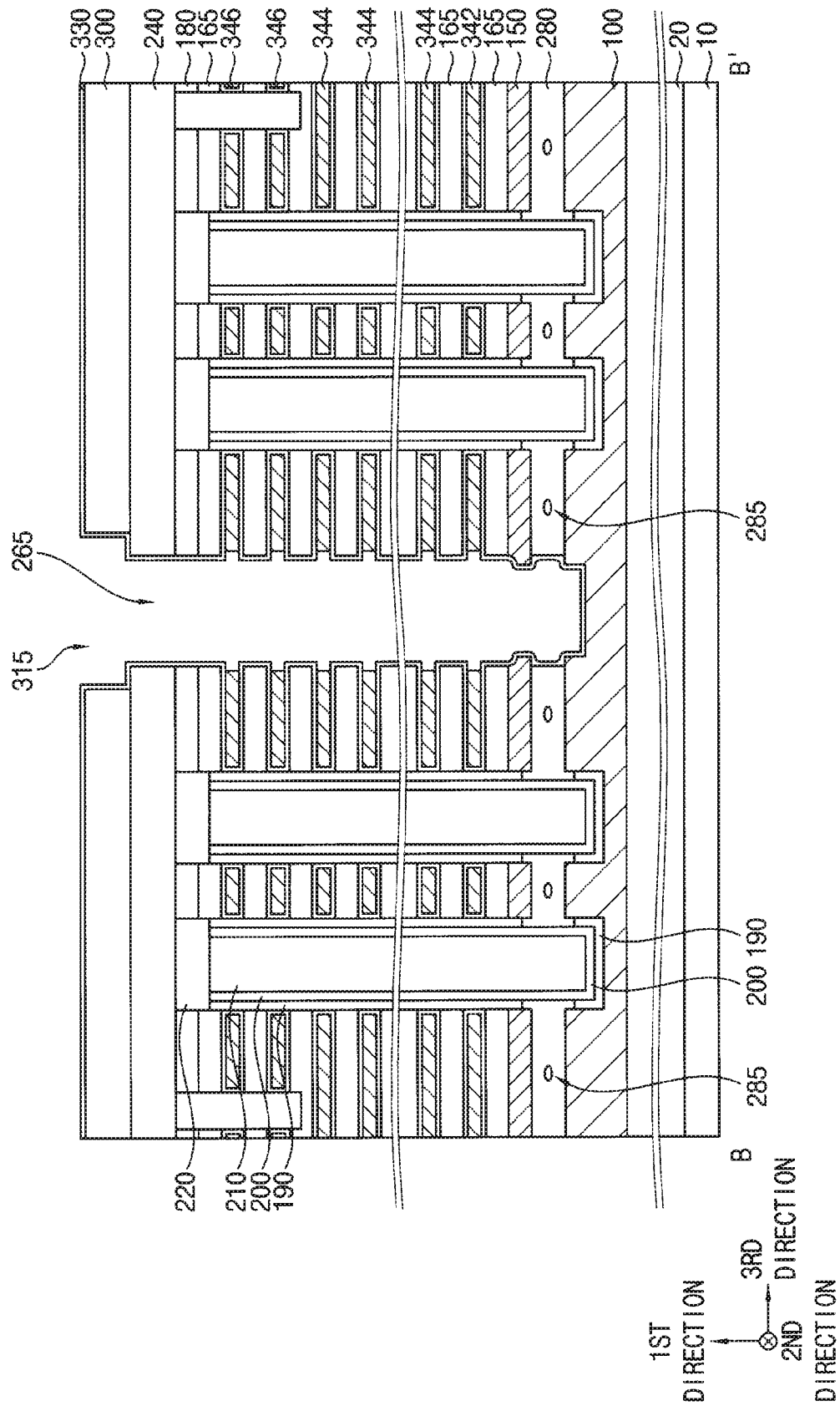


FIG. 23



5
E
G
25

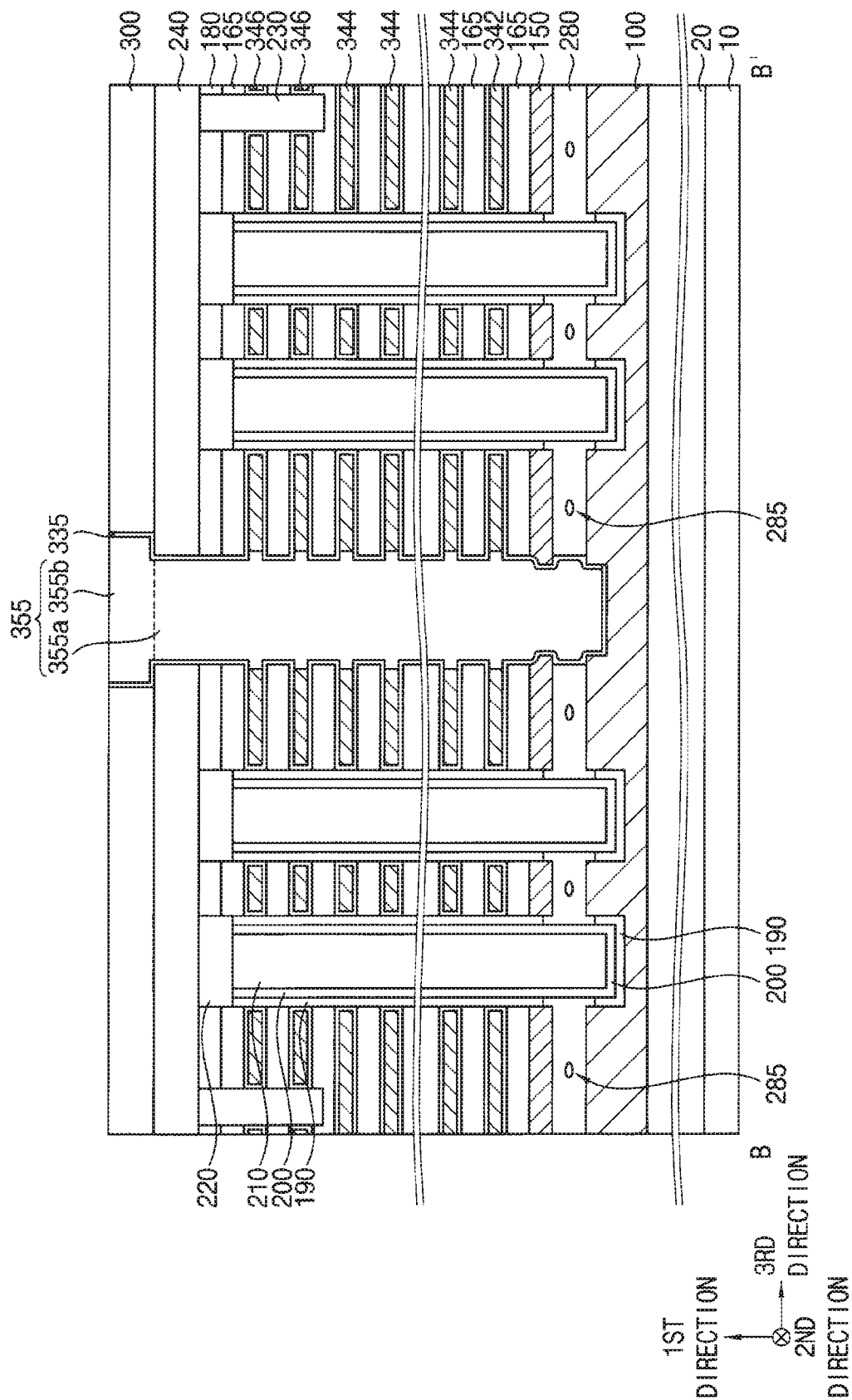


FIG. 26

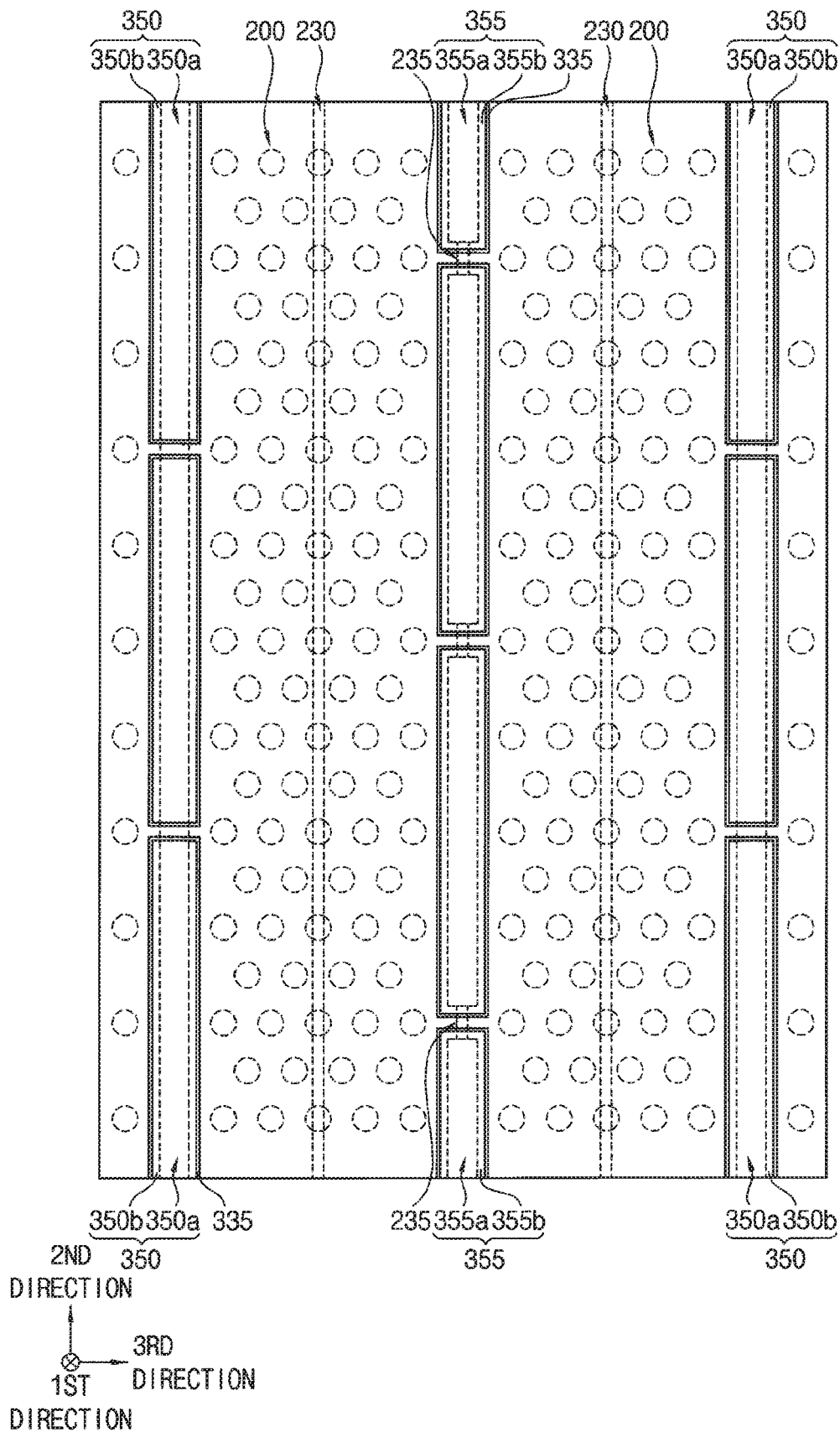


FIG. 27

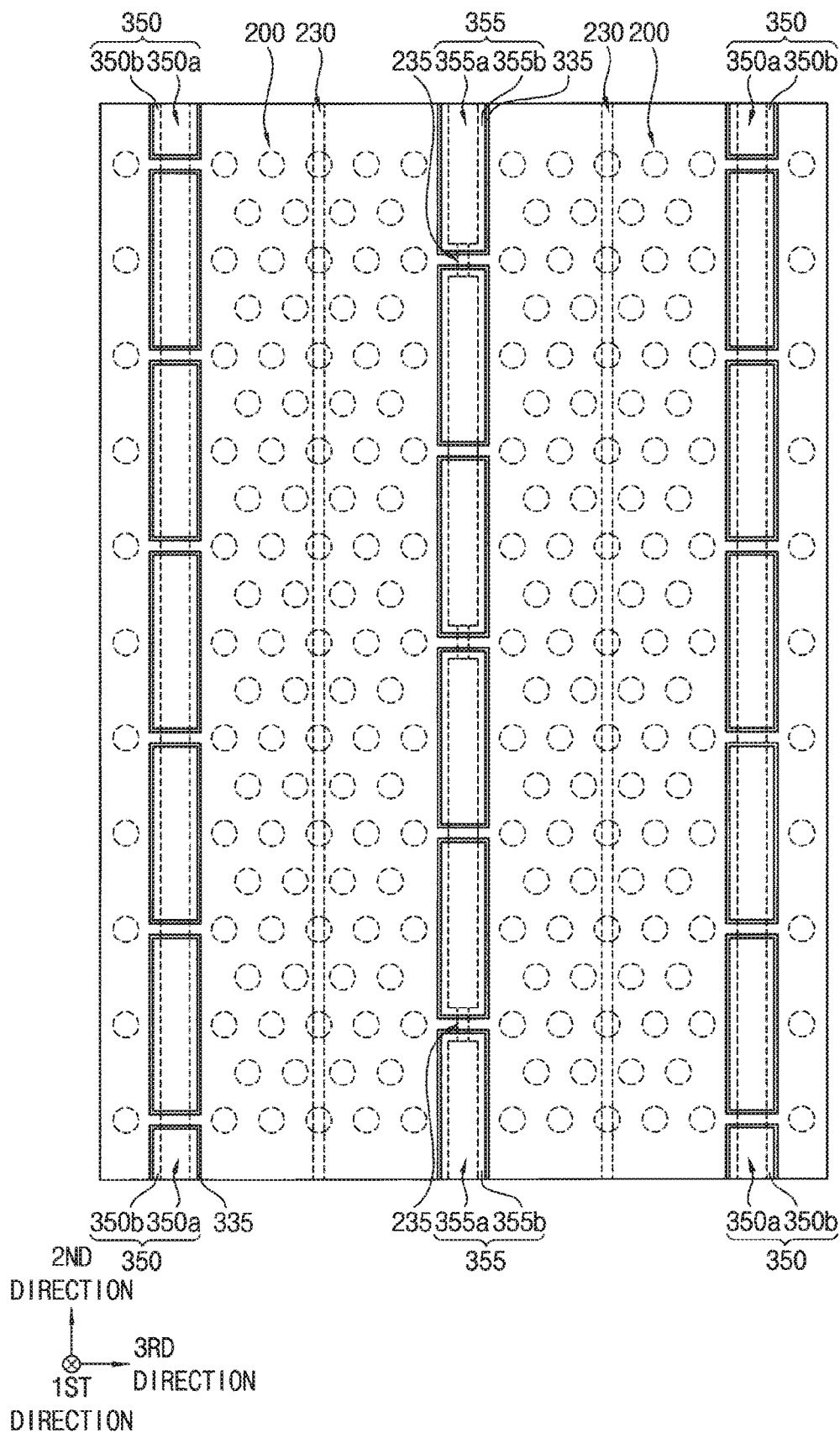


FIG. 28

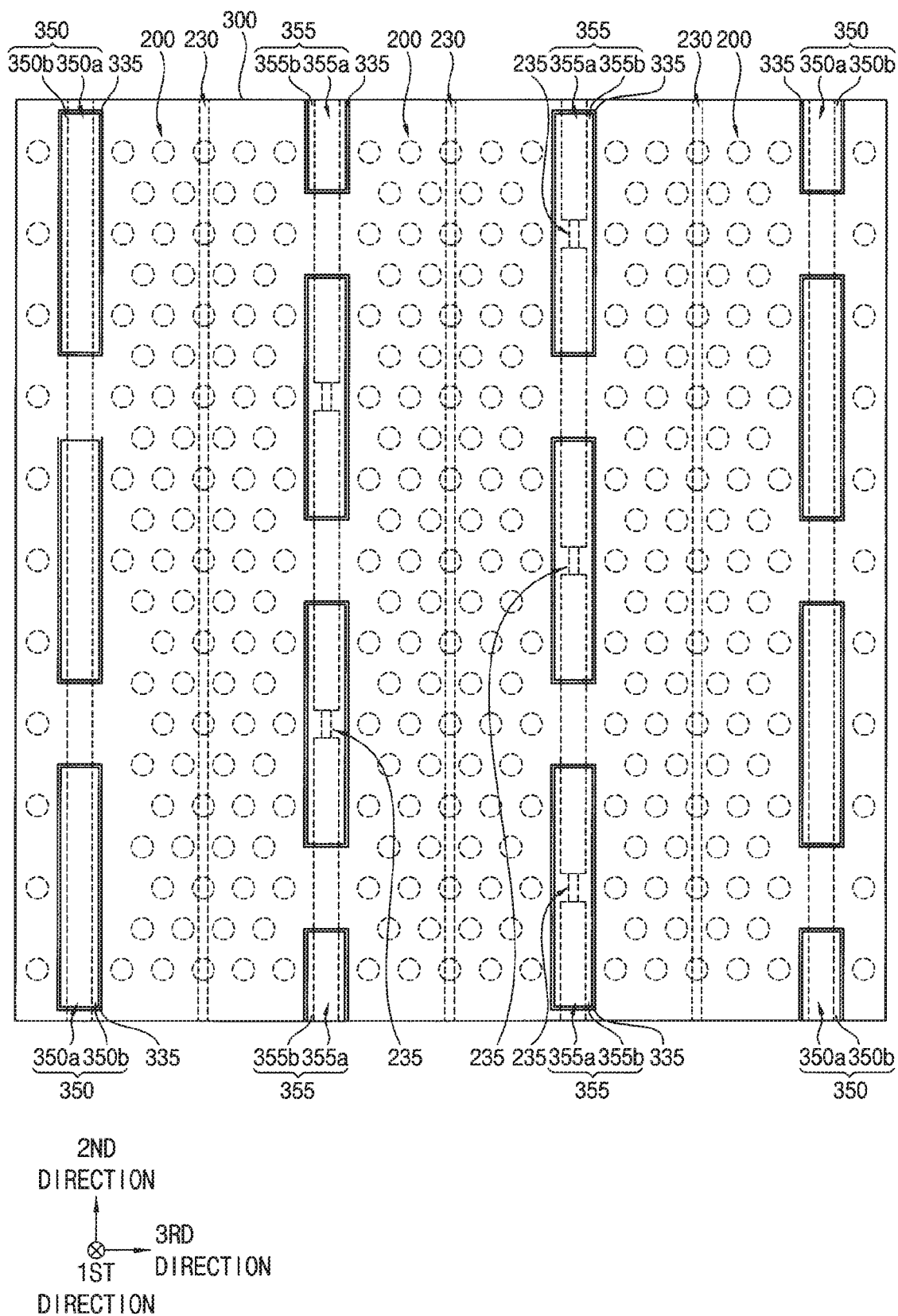


FIG. 29

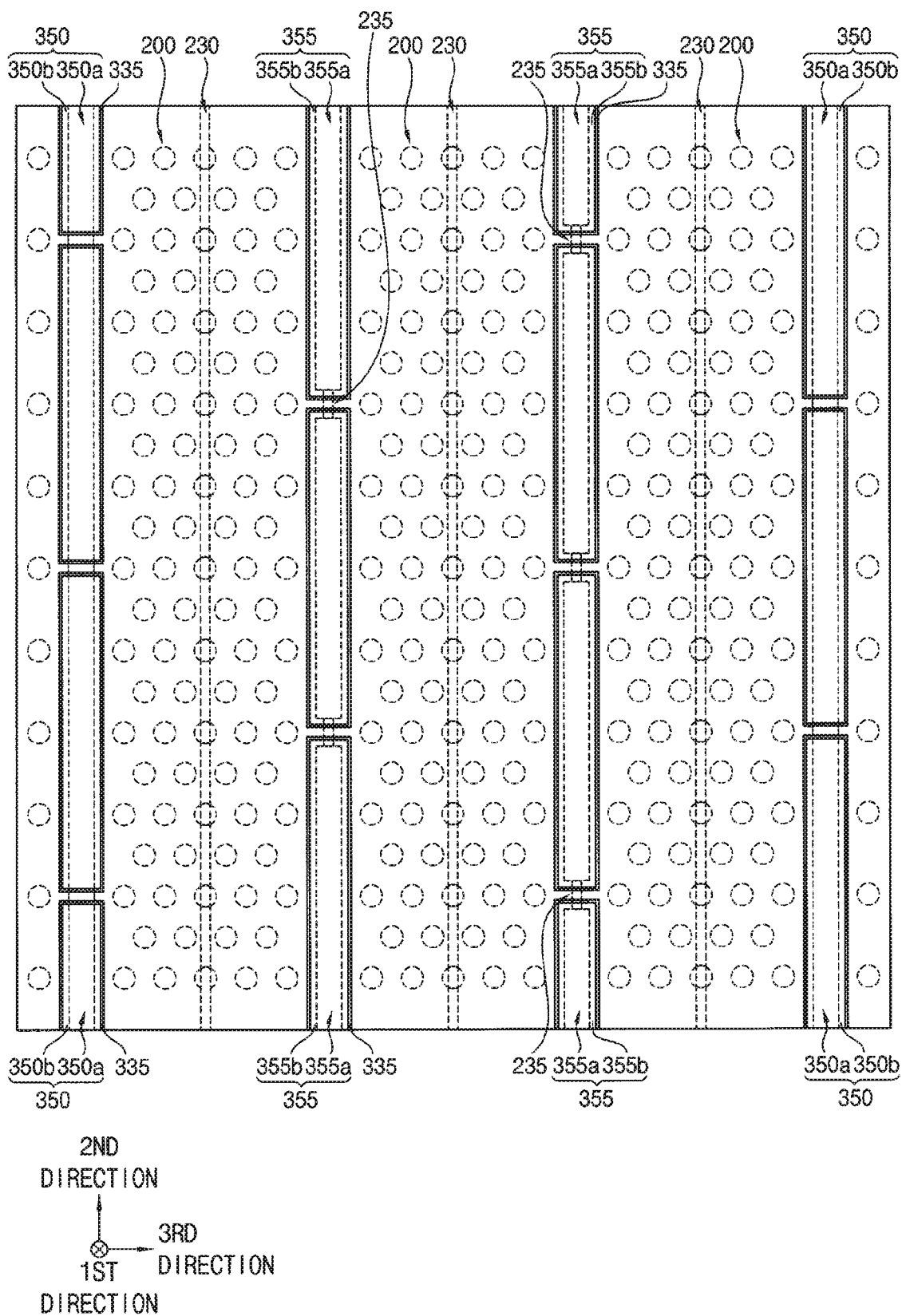
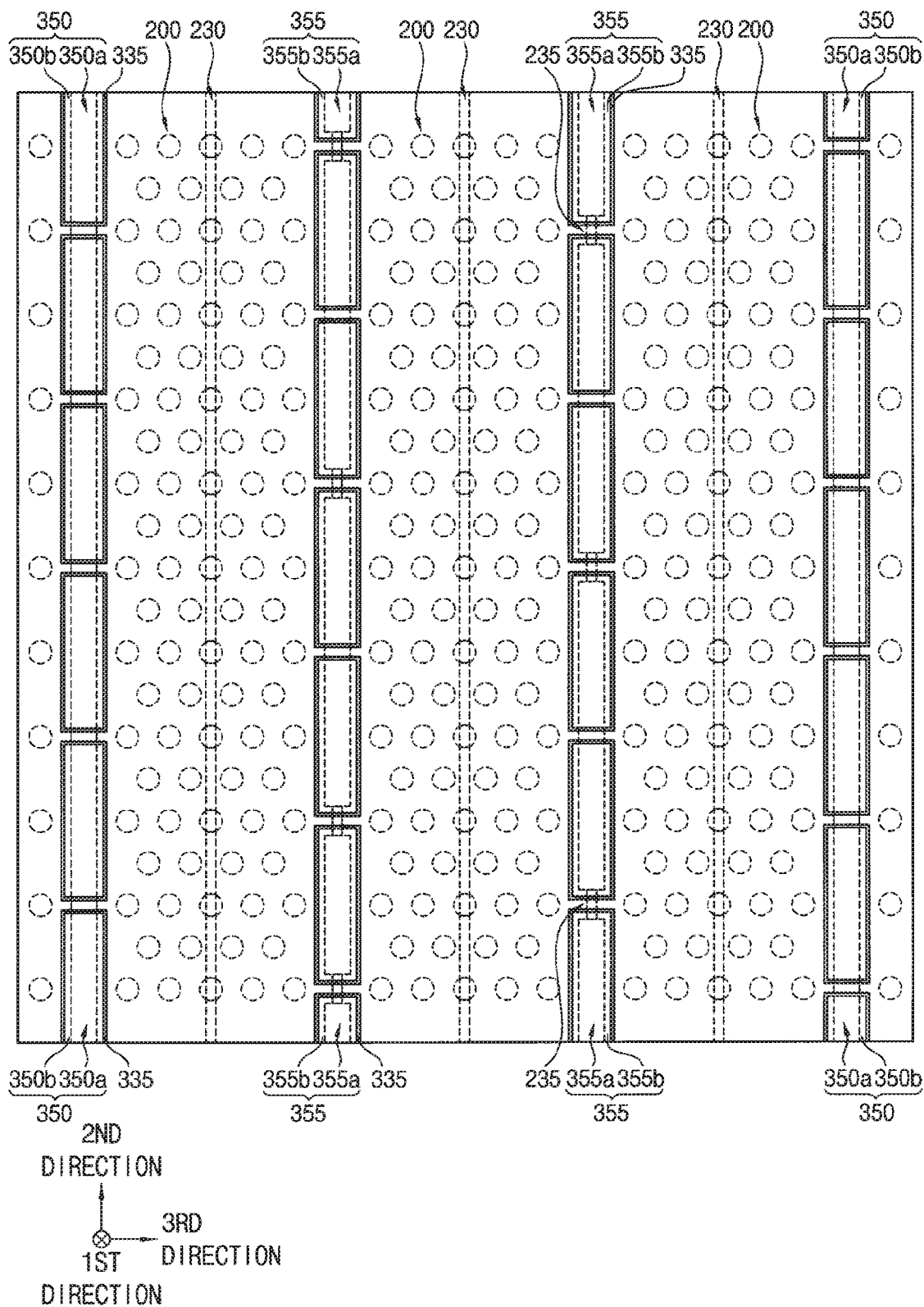


FIG. 30



1

VERTICAL MEMORY DEVICE WITH SUPPORT LAYER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. § 119 to Korean Patent Application No. 10-2019-0136325, filed on Oct. 30, 2019 in the Korean Intellectual Property Office (KIPO), the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

Exemplary embodiments of the inventive concept relate to a vertical memory device.

DISCUSSION OF RELATED ART

In a VNAND flash memory device, as the number of stacked gate electrodes increases, a mold including sacrificial layers for forming the gate electrodes may be bent or fall down.

SUMMARY

According to an exemplary embodiment of the inventive concept, a vertical memory device may include gate electrode structures, channels, a first division pattern, second and third division patterns, and a first support layer. Each of the gate electrode structures may include gate electrodes spaced apart from one another on a substrate in a first direction substantially perpendicular to an upper surface of the substrate, and extending in a second direction substantially parallel to the upper surface of the substrate. The gate electrode structures may be spaced apart from one another in a third direction substantially parallel to the upper surface of the substrate and crossing the second direction. Each of the channels may extend through one of the gate electrode structures in the first direction. The first division pattern may extend in the second direction between first ones of the gate electrode structures neighboring in the third direction. The second and third division patterns may be alternately disposed in the second direction between second ones of the gate electrode structures neighboring in the third direction. The first support layer may be formed on the gate electrode structures at substantially the same height as upper portions of the first and second division patterns. The first support layer may contact the upper portions of the first and second division patterns. The upper portions of the first division patterns and the upper portions of the second division patterns may be arranged in a zigzag pattern in the second direction in a plan view.

According to an exemplary embodiment of the inventive concept, a vertical memory device may include gate electrode structures, channels, a first division pattern, a second division pattern, third division patterns, and a support layer. Each of the gate electrode structures may include gate electrodes spaced apart from one another on a substrate in a first direction substantially perpendicular to an upper surface of the substrate, and extending in a second direction substantially parallel to the upper surface of the substrate. The gate electrode structures may be spaced apart from one another in a third direction substantially parallel to the upper surface of the substrate and crossing the second direction. The channels may each extend through one of the gate electrode structures in the first direction. The first division

2

pattern may include a first lower portion and first upper portions. The first lower portion may extend in the second direction between first ones of the gate electrode structures neighboring in the third direction to separate the first ones of the gate electrode structures from one another. The first upper portions may be spaced apart from one another in the second direction, and contact an upper surface of the first lower portion. The second division pattern may include second lower portions and second upper portions. The second lower portions may be spaced apart from one another in the second direction and disposed between second ones of the gate electrode structures. The second upper portions may contact upper surfaces of the second lower portions. The third division patterns may be disposed between the second lower portions of the second division pattern. The support layer may be formed on the gate electrode structures, and may face sidewalls of the first and second upper portions of the first and second division patterns, respectively.

According to an exemplary embodiment of the inventive concept, a vertical memory device may include gate electrode structures, channels, first division patterns, second division patterns, a support layer, and first and second insulation patterns. Each of the gate electrode structures may include gate electrodes spaced apart from one another on a substrate in a first direction substantially perpendicular to an upper surface of the substrate, and extending in a second direction substantially parallel to the upper surface of the substrate. The gate electrode structures may be spaced apart from one another in a third direction substantially parallel to the upper surface of the substrate and crossing the second direction. The channels may each extend through one of the gate electrode structures in the first direction. Each of the first division patterns may extend in the second direction between first ones of the gate electrode structures neighboring in the third direction to separate the first ones of the gate electrode structures from one another. The second division patterns may be spaced apart from one another in the second direction between second ones of the gate electrode structures neighboring in the third direction. The support layer may be formed on the gate electrode structures and the first and second division patterns, and may include first and second openings at least partially exposing upper surfaces of the first and second division patterns, respectively. The first and second insulation patterns may fill the first and second openings, respectively. The first and second insulation patterns may be arranged in a zigzag pattern in the third direction.

According to an exemplary embodiment of the inventive concept, a vertical memory device may include a common source plate (CSP), a channel connection pattern, a first support layer, gate electrode structures, channels, a first division pattern, second and third division patterns, and a second support layer. The CSP may be formed on a substrate. The channel connection pattern and the first support layer may be sequentially stacked on the CSP in a first direction substantially perpendicular to an upper surface of the substrate. The gate electrode structures may each include gate electrodes spaced apart from one another on the first support layer in the first direction, and extending in a second direction substantially parallel to the upper surface of the substrate. The gate electrode structures may be spaced apart from one another in a third direction substantially parallel to the upper surface of the substrate and crossing the second direction. The channels may each extend in the first direction through one of the gate electrode structures, the first support layer, and the channel connection pattern on the CSP, and the channels may be electrically connected to one another. The

first division pattern may extend in the second direction between first ones of the gate electrode structures neighboring in the third direction to separate the first ones of the gate electrode structures from one another. The second and third division patterns may be alternately disposed in the second direction between second ones of the gate electrode structures neighboring in the third direction to separate the second ones of the gate electrode structures from one another. The second support layer may be formed on the gate electrode structures at substantially the same height as upper portions of the first and second division patterns. The upper portions of the first division pattern and the upper portions of the second division patterns may be arranged in a zigzag pattern in the second direction.

A method of manufacturing a vertical memory device may include forming a common source plate (CSP) on a substrate in a first direction, forming a plurality of insulation layers and a plurality of sacrificial layers that are alternately stacked in the first direction to form a mold on the CSP, etching the mold to form a first opening exposing the CSP and dividing the plurality of sacrificial layers into sacrificial patterns, where the second opening separates the sacrificial patterns in a third direction crossing the first direction, forming first division patterns in the first opening, forming second and third openings extending in a second direction crossing the first and third directions, where the second openings are disposed between the second division patterns in the second direction, forming a first support layer on the mold and the first division pattern, where the first support layer includes fourth and fifth openings, removing the sacrificial patterns to form a gap between the plurality of insulation layers, forming gate electrodes in the gap, where the gate electrodes are alternately stacked with the plurality of insulation layers, filling the second to fifth openings to form a division layer, and planarizing the division layer until the first support layer is exposed to form second and third division patterns, where the second division pattern is disposed in the second and fourth openings and the third division pattern is disposed in the third and fifth openings. The first and third division patterns are alternately disposed in the second direction.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1, 2A, 2B, and 3 are a plan view and cross-sectional views illustrating a vertical memory device in accordance with exemplary embodiments of the inventive concept.

FIGS. 4 to 25 are plan views and cross-sectional views illustrating a method of manufacturing a vertical memory device in accordance with exemplary embodiments of the inventive concept.

FIGS. 26 and 27 are plan views illustrating vertical memory devices in accordance with exemplary embodiments of the inventive concept.

FIGS. 28 to 30 are plan views illustrating vertical memory devices in accordance with exemplary embodiments of the inventive concept.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Exemplary embodiments of the inventive concept provide a vertical memory device having improved characteristics.

Exemplary embodiments of the inventive concept will be described more fully hereinafter with reference to the accompanying drawings. Like reference numerals may refer to like elements throughout this application.

It will be understood that, although the terms “first,” “second,” “third,” etc. may be used herein to describe various elements, components, regions, layers, and/or sections, these elements, components, regions, layers, and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer, or section from another region, layer, or section. Thus, a first element, component, region, layer, or section discussed below could be termed a second or third element, component, region, layer, or section without departing from the teachings of inventive concept.

Hereinafter in the specification (not necessarily in the claims), a direction substantially perpendicular to an upper surface of a substrate may be referred to as a first direction, and two directions substantially parallel to the upper surface of the substrate and crossing each other may be referred to as second and third directions, respectively. In exemplary embodiments of the inventive concept, the second and third directions may be substantially perpendicular to each other.

FIGS. 1, 2A, 2B, and 3 are a plan view and cross-sectional views illustrating a vertical memory device in accordance with exemplary embodiments of the inventive concept. FIG. 1 is the plan view, FIGS. 2A and 2B are cross-sectional views taken along a line A-A' of FIG. 1, and FIG. 3 is a cross-sectional view taken along a line B-B' of FIG. 1. In order to avoid complexity of the drawings, FIG. 1 does not show fourth and fifth insulating interlayers, contact plugs, and wirings.

Referring to FIGS. 1, 2A, and 3, the vertical memory device may include a common source plate (CSP) 100, a channel connection pattern 280, a first support layer 150, a second support layer 300, a gate electrode structure, a channel 200, a charge storage structure 190, and first to fourth division patterns 230, 235, 350, and 355 on a substrate 10. The vertical memory device may further include lower circuit patterns, a filling pattern 210, a capping pattern 220, an insulation pattern 165, first to fourth insulating interlayers 20, 180, 240, and 360, a fifth insulating interlayer, a contact plug 370, and an upper wiring 380.

The substrate 10 may include silicon, germanium, silicon-germanium, or a III-V compound such as GaP, GaAs, GaSb, etc. In exemplary embodiments of the inventive concept, the substrate 10 may be a silicon-on-insulator (SOI) substrate or a germanium-on-insulator (GOI) substrate.

In exemplary embodiments of the inventive concept, the vertical memory device may have a cell over periphery (COP) structure. In other words, the lower circuit patterns may be formed on the substrate 10, and memory cells may be formed over the lower circuit patterns. The lower circuit patterns may include, e.g., transistors, lower contact plugs, lower wirings, lower vias, etc. The lower circuit patterns may be covered by the first insulating interlayer 20 on the substrate 10.

The CSP 100 may be formed on the first insulating interlayer 20, and may include, e.g., polysilicon doped with n-type impurities.

The gate electrode structure may include gate electrodes 342, 344, and 346 spaced apart from each other in the first direction on the CSP 100. Each of the gate electrodes 342, 344, and 346 may extend in the second direction. Lengths of the gate electrodes 342, 344, and 346 extending in the second direction may decrease from lower levels to upper levels, and thus the gate electrode structure may have a staircase shape.

The gate electrodes 342, 344, and 346 may include first, second and third gate electrodes 342, 344, and 346 sequentially stacked in the first direction. The first gate electrode

342 may serve as a ground selection line (GSL), each of the second gate electrodes **344** may serve as a word line, and the third gate electrode **346** may serve as a string selection line (SSL).

Each of the first to third gate electrodes **342**, **344**, and **346** may be formed at one or a plurality of levels. In exemplary embodiments of the inventive concept, the first gate electrode **342** may be formed at a lowermost level, the third gate electrode **346** may be formed at an uppermost level and one level directly under the uppermost level, and the second gate electrode **344** may be formed at a plurality of levels between the first and third gate electrodes **342** and **346**. The uppermost level is furthest from the substrate **10** and the lowermost level is closest to the substrate **10**. Or in other words, the uppermost level (or an upper level) is closer to the first support layer **150** than to the substrate **10**.

Each of the first to third gate electrodes **342**, **344**, and **346** may include a conductive pattern and a barrier pattern covering lower and upper surfaces and a sidewall of the conductive pattern. The conductive pattern may include a low resistance metal, e.g., tungsten, titanium, tantalum, platinum, etc., and the barrier pattern may include a metal nitride, e.g., titanium nitride, tantalum nitride, etc.

Lower and upper surfaces and a sidewall facing the channel **200** of each of the gate electrodes **342**, **344**, and **346** may be covered by a second blocking pattern **335**. The second blocking pattern **335** may include a metal oxide, e.g., aluminum oxide, hafnium oxide, etc., and thus may be referred to as a metal oxide pattern. The second blocking pattern **335** may also cover sidewalls of the insulation patterns **165**, the first and second support layers **150** and **300**, the channel connection pattern **280**, the second and third insulating interlayers **180** and **240**, and an upper surface of the CSP **100**.

The insulation pattern **165** may be formed between the gate electrodes **342**, **344**, and **346** that neighbor each other in the first direction, and the gate electrodes **342**, **344**, and **346** and the insulation patterns **165** may form a mold having a staircase shape. The insulation pattern **165** may include an oxide, e.g., silicon oxide.

In exemplary embodiments of the inventive concept, the gate electrode structure may extend in the second direction, and a plurality of gate electrode structures may be formed in the third direction. The second to fourth division patterns **235**, **350**, and **355** may be formed between the gate electrode structures, which may be separated from one another in the third direction.

The third division pattern **350** may include a first lower portion **350a** extending in the second direction between the gate electrode structures, and first upper portions **350b**, each of which may contact an upper surface of the first lower portion **350a**, spaced apart from each other in the second direction. The gate electrode structures may be separated from each other in the third direction by the first lower portion **350a** of the third division pattern **350**.

In an exemplary embodiment of the inventive concept, a width in the third direction of each of the first upper portions **350b** may be greater than a width in the third direction of the first lower portion **350a**; however, the inventive concept may not be limited thereto. The second blocking pattern **335** may cover a portion of a sidewall of the first lower portion **350a** of the third division pattern **350** and a sidewall of the first upper portion **350b** of the third division pattern **350**. A plurality of third division patterns **350** may be spaced apart from one another in the third direction.

The fourth division pattern **355** may include second lower portions **355a** spaced apart from one another in the second

direction between the gate electrode structures, and second upper portions **355b** each commonly contacting upper surfaces of the second lower portions **355a** neighboring each other in the second direction (e.g., neighboring second lower portions). In exemplary embodiments of the inventive concept, the fourth division pattern **355** may be formed between the third division patterns **350** neighboring each other in the third direction (e.g., neighboring third division patterns).

In an exemplary embodiment of the inventive concept, a width in the third direction of each of the second upper portions **355b** may be greater than a width in the third direction of each of the second lower portions **355a**; however, the inventive concept may not be limited thereto. The second blocking pattern **335** may cover a portion of a sidewall of the second lower portion **355a** of the fourth division pattern **355**, and a sidewall of the second upper portion **355b** of the fourth division pattern **355**. In other words, the second upper portions **355b** and the lower portions **355a** of the fourth division pattern **355** may be similar to the first upper portions **350b** and the first lower portion **350a** of the third division pattern **350**; however, the inventive concept is not limited thereto.

In exemplary embodiments of the inventive concept, the first upper portions **350b** of the third division pattern **350** and the second upper portions **355b** of the fourth division pattern **355** may be arranged in a zigzag pattern along the second direction or the third direction in a plan view. In exemplary embodiments of the inventive concept, each of the first upper portions **350b** of the third division pattern **350** may partially overlap in the third direction at least one of the second upper portions **355b** of the fourth division patterns **355**. In exemplary embodiments of the inventive concept, the first upper portions **350b** of the third division pattern **350** and the second upper portions **355b** of the fourth division pattern **355** may be disposed at substantially the same height.

The third and fourth division patterns **350** and **355** may include substantially the same material, e.g., an oxide such as silicon oxide. Thus, the third and fourth division patterns **350** and **355** may be referred to as first and second insulation patterns, respectively. Alternatively, the first and second upper portions **350b** and **355b** or the first and second lower portions **350a** and **355a** of the third and fourth division patterns **350** and **355** may be referred to as the first and second insulation patterns, respectively. If the first and second upper portions **350b** and **355b** of the third and fourth division patterns **350** and **355** are referred to as the first and second insulation patterns, respectively, the first and second insulation patterns may be arranged in a zigzag pattern along the second direction or the third direction, and each of the first insulation patterns may partially overlap at least one of the second insulation patterns in the third direction.

The second division pattern **235** may be formed between the second lower portions **355a** of the fourth division patterns **355** neighboring each other in the second direction, and may be connected thereto. Thus, the gate electrode structures may be separated from one another in the third direction by the second division patterns **235** and the second lower portions **355a** of the fourth division pattern **355**. In exemplary embodiments of the inventive concept, each of the second division patterns **235** may overlap the second lower portion **355a** of the fourth division pattern **355** in the first direction.

In exemplary embodiments of the inventive concept, an upper surface of the second division pattern **235** may be substantially coplanar with an upper surface of the second insulating interlayer **180** on an uppermost one of the insu-

lation patterns **165** and the capping pattern **220**, and thus may be lower than upper surfaces of the first and second lower portions **350a** and **355a** of the third and fourth division patterns **350** and **355**, which may be substantially coplanar with an upper surface of the third insulating interlayer **240** on the second insulating interlayer **180**. In other words, a distance of the upper surfaces of the first and second lower portions **350a** and **355a** of the third and fourth division patterns **350** and **355** from the substrate **10** is greater than a distance of the upper surface of the second division pattern **235** from the substrate **10**.

The second division pattern **235** may include an oxide, e.g., silicon oxide. Therefore, the second to fourth division patterns **235**, **350**, and **355** may include substantially the same material.

The channel **200** may be formed in a channel hole extending through the mold, which may include the first to third gate electrodes **342**, **344**, and **346** sequentially stacked in the first direction and the insulation patterns **165** interposed therebetween, and the second insulating interlayer **180** to expose an upper surface of the CSP **100**. Thus, the channel **200** may extend in the first direction.

For example, the channel **200** may extend in the first direction on the CSP **100**, and may have a cup-like shape. The channel **200** may include undoped or doped polysilicon or single crystalline silicon.

In exemplary embodiments of the inventive concept, the channel **200** may be formed in each of the second and third directions. A plurality of channels **200** arranged in the second direction may form a channel column, a plurality of channel columns arranged in the third direction may form a channel group, and a plurality of channel groups arranged in the third direction may form a channel block. In the figures, one channel block includes two channel groups, and each of the channel groups includes nine channel columns; however, the inventive concept may not be limited thereto.

The charge storage structure **190** may include an upper portion extending in the first direction to cover most of an outer sidewall of the channel **200** and having a hollow cylindrical shape, and a lower portion covering a bottom surface and a lower sidewall of the channel **200** on the CSP **100** and having a cup-like shape. The lower portion of the charge storage structure **190** may be spaced apart from the upper portion of charge storage structure **190**. Each of the lower and upper portions of the charge storage structure **190** may include a tunnel insulation pattern, a charge storage pattern, and a first blocking pattern sequentially stacked from the outer sidewall and/or the bottom surface of the channel **200**.

The tunnel insulation pattern and the first blocking pattern may include an oxide, e.g., silicon oxide, and the charge storage pattern may include a nitride, e.g., silicon nitride.

The filling pattern **210** may fill an inner space formed by an inner sidewall of the channel **200**. The filling pattern **210** may include an oxide, e.g., silicon oxide.

The channel **200**, the charge storage structure **190**, and the filling pattern **210** may be formed in the channel hole on the CSP **100**, and the capping pattern **220** may be formed in an upper portion of the channel hole, e.g., on the channel **200**, the charge storage structure **190** and the filling pattern **210**. The capping pattern **220** may include, e.g., polysilicon doped with n-type impurities.

The first division pattern **230** may extend through upper portions of the channels **200** included in the channel column at a central portion in the third direction of each channel group, and may extend in the second direction. In other words, the first division pattern **230** may extend in the

second direction between the third and fourth division patterns **350** and **355**. In exemplary embodiments of the inventive concept, the first division pattern **230** may extend through not only the upper portions of the channels **200** but also upper portions of the charge storage structure **190** and the filling pattern **210**, the capping pattern **220**, the second insulating interlayer **180**, the insulation patterns **165**, and the third gate electrodes **236** at the upper two levels. Thus, the third gate electrodes **346** at the upper two levels, in the gate electrode structure may be separated from each other in the third direction by the first division pattern **230**.

The channel connection pattern **280** and the first support layer **150** may be sequentially stacked in the first direction on the CSP **100**. The channel connection pattern **280** may contact a lower outer sidewall of each of the channels **200**, e.g., an outer sidewall of each of the channels **200**, which may be formed between the lower and upper portions of the charge storage structure **190** not covered by the charge storage structure **190**, and thus, the channels **200** included in each of the channel group may be connected with each other. The channel connection pattern **280** may include, e.g., polysilicon doped with n-type impurities, and may have an air gap **285** therein.

The first support layer **150** may be formed between the channel connection pattern **280** and the first gate electrode **342**. However, a portion of the first support layer **150** may extend through the channel connection pattern **280** to contact an upper surface of the CSP **100**, which may be referred to as a support pattern. A plurality of support patterns may be formed, and may have various types of layouts. The first support layer **150** may include, e.g., polysilicon doped with n-type impurities.

The second insulating interlayer **180** may cover the mold, and may be formed on the CSP **100** and the uppermost one of the insulation patterns **165**. The third insulating interlayer **240** may be formed on the second insulating interlayer **180**, the capping pattern **220**, and the first and second division patterns **230** and **235**.

The second support layer **300** may be formed on the third insulating interlayer **240**, and may include fifth and sixth openings **310** and **315** (refer to FIG. 18). Thus, the second support layer **300** may be formed at substantially the same height as the first and second upper portions **350b** and **355b** of the third and fourth division patterns **350** and **355** in the fifth and sixth openings **310** and **315**, respectively, and may face a portion of the second blocking pattern **335** on sidewalls of the fifth and sixth openings **310** and **315**. The second support layer **300** may include an oxide, e.g., silicon oxide.

The fourth insulating interlayer **360** may be formed on the second support layer **300**, and the first upper portions **350b** and **355b** of the third and fourth division patterns **350** and **355**, and the fifth insulating interlayer may be formed on the fourth insulating interlayer **360**.

The contact plug **370** may extend through the third and fourth insulating interlayers **240** and **360** and the second support layer **300** to contact an upper surface of the capping pattern **220**, and the upper wiring **380** may extend in the third direction to contact the contact plugs **370**. In exemplary embodiments of the inventive concept, a plurality of upper wirings **380** may be formed in the second direction. The upper wiring **380** may serve as a bit line of the vertical memory device.

The fourth division pattern **355** may include a protrusion portion **355c**. At least a portion of the protrusion portion **355c** may be formed at substantially the same height as the channel connection pattern **280** to protrude under the second

division pattern **235** in the second direction. A surface of the protrusion portion **355c** of the fourth division pattern **355** may be covered by the second blocking pattern **335**.

Alternatively, referring to FIG. 2B, instead of the protrusion portion **355c** of the fourth division pattern **355**, the channel connection pattern **280** may be formed under the second division pattern **235**. In this case, the channels **200** included in each of channel groups neighboring in the second direction may be electrically connected to one another by the channel connection pattern **280**.

As illustrated above, the vertical memory device may include the second to fourth division patterns **235**, **350**, and **355** between the gate electrode structures, and the second support layer **300** on the gate electrode structures. Therefore, the mold including the gate electrode structures may not be bent or fall down even though the mold has a high upper surface or a long extension length, which will be illustrated and described below.

FIGS. 4 to 25 are plan views and cross-sectional views illustrating a method of manufacturing a vertical memory device in accordance with exemplary embodiments of the inventive concept. FIGS. 4, 6, 8, 10, 16, 18, and 20 are the plan views, and FIGS. 5, 7, 9, 11-15, 17, 19, and 21-25 are the cross-sectional views.

FIGS. 5, 7, 9, 12, 14, 22 and 24 are cross-sectional views taken along lines A-A' of corresponding plan views, and FIGS. 11, 13, 15, 17, 19, 21, 23 and 25 are cross-sectional views taken along lines B-B' of corresponding plan views.

Referring to FIGS. 4 and 5, lower circuit patterns may be formed on the substrate **10**, and the first insulating interlayer **20** may be formed on the substrate **10** to cover the first insulating interlayer **20**.

The CSP **100**, a sacrificial layer structure **140**, and the first support layer **150** may be sequentially formed on the first insulating interlayer **20**.

The sacrificial layer structure **140** may include first to third sacrificial layers **110**, **120** and **130** sequentially stacked. Each of the first and third sacrificial layers **110** and **130** may include an oxide, e.g., silicon oxide, and the second sacrificial layer **120** may include a nitride, e.g., silicon nitride.

The first support layer **150** may include a material having an etching selectivity with respect to the first to third sacrificial layers **110**, **120** and **130**, e.g., polysilicon doped with n-type impurities. In exemplary embodiments of the inventive concept, the first support layer **150** may be formed by depositing amorphous silicon doped with n-type impurities, and by performing a heat treatment or by being crystallized through heat generated during the deposition process for other structures to include polysilicon doped with n-type impurities.

An insulation layer **160** and a fourth sacrificial layer **170** may be alternately and repeatedly formed on the first support layer **150**, and thus a mold layer including the insulation layers **160** and the fourth sacrificial layers **170** may be formed. The insulation layer **160** may include an oxide, e.g., silicon oxide, and the fourth sacrificial layer **170** may include a material having an etching selectivity with respect to the insulation layer **160**, e.g., a nitride such as silicon nitride.

Referring to FIGS. 6 and 7, an etching process using a photoresist pattern as an etching mask and a trimming process for reducing an area of the photoresist pattern may be alternately and repeatedly performed to form a mold having a plurality of step layers each including the fourth sacrificial layer **170** and the insulation layer **160** sequentially stacked and having a staircase shape.

The second insulating interlayer **180** may be formed on the CSP **100** to cover the mold, and a channel hole may be formed through the second insulating interlayer **180**, the mold, the first support layer **150**, and the sacrificial layer structure **140** to expose an upper surface of the CSP **100**. A plurality of channel holes may be formed in each of the second and third directions.

A charge storage structure layer and a channel layer may be formed on a sidewall of each of the channel holes, the exposed upper surface of the CSP **100**, and an upper surface of the second insulating interlayer **180**, and a filling layer may be formed on the channel layer to fill the channel holes. The filling layer, the channel layer and the charge storage structure layer may be planarized until the upper surface of the second insulating interlayer **180** may be exposed to form the charge storage structure **190**, the channel **200**, and the filling pattern **210** in each of the channel holes.

In exemplary embodiments of the inventive concept, a plurality of channels **200** may be formed in each of the second and third directions. The plurality of channels **200** arranged in the second direction may form a channel column, a plurality of channel columns arranged in the third direction may form a channel group, and a plurality of channel groups arranged in the second third may form a channel block.

In exemplary embodiments of the inventive concept, the charge storage structure **190** may include a tunnel insulation pattern, a charge storage pattern, and a first blocking pattern sequentially stacked in a horizontal direction substantially parallel to the upper surface of the substrate **10** from an outer sidewall of the channel **200**.

An upper portion of a pillar structure including the charge storage structure **190**, the channel **200**, and the filling pattern **210** stacked in each of the channel holes may be removed to form a trench, and the capping pattern **220** may be formed to fill the trench.

Referring to FIGS. 8 and 9, the second insulating interlayer **180**, some of the insulation layers **160**, and some of the fourth sacrificial layers **170** may be etched to form a first opening extending in the second direction, and the first division pattern **230** may be formed to fill the first opening.

In an exemplary embodiment of the inventive concept, the first division pattern **230** may extend through upper portions of the channels **200** included in the channel column at a central portion in the third direction of each channel group. In exemplary embodiments of the inventive concept, the first division pattern **230** may extend through not only the upper portions of the channels **200** but also the fourth sacrificial layers **170** at the upper two levels, respectively, and the insulation layers **160** at the upper two levels, and a portion of one of the insulation layers **160** directly thereunder. The first division pattern **230** may extend in the second direction, and may extend through upper two step layers included in the mold. Thus, the fourth sacrificial layers **170** at the upper two levels may be separated from each other in the third direction by the first division pattern **230**.

Additionally, the second insulating interlayer **180**, the mold, the first support layer **150**, and the sacrificial layer structure **140** may be etched to form a second opening exposing an upper surface of the CSP **100**, and the second division pattern **235** may be formed in the second opening. In exemplary embodiments of the inventive concept, a plurality of second division patterns **235** may be spaced apart from one another in the second direction between the first division patterns **230** neighboring in the third direction, more particularly, between the channel groups neighboring in the third direction in each channel block.

11

The first and second division patterns **230** and **235** may be formed by the same etching process and deposition process, or by independent etching processes and deposition processes.

Referring to FIGS. **10** and **11**, the third insulating interlayer **240** may be formed on the second insulating interlayer **180**, the capping pattern **220**, and the first and second division patterns **230** and **235**, and third and fourth openings **260** and **265** may be formed through the second and third insulating interlayers **180** and **240** and the mold by, e.g., a dry etching process.

The dry etching process may be formed until each of the third and fourth openings **260** and **265** may expose an upper surface of the first support layer **150**, and each of the third and fourth openings **260** and **265** may extend through an upper portion of the first support layer **150**. The insulation layers **160** and the fourth sacrificial layers **170** included in the mold may be exposed by the third and fourth openings **260** and **265**.

In exemplary embodiments of the inventive concept, the third opening **260** may extend in the second direction between the channel blocks neighboring in the third direction, and a plurality of third openings **260** may be formed in the third direction. In exemplary embodiments of the inventive concept, the fourth opening **265** may be formed between the second division patterns **235** arranged in the second direction, and may be connected to end portions in the second direction of each of the second division patterns **235**. In other words, a plurality of fourth openings **265** may be spaced apart from one another in the second direction, and each of the fourth openings **265** may be formed between channel groups neighboring in the third direction in each of channel blocks.

As the second division pattern **235** and the third and fourth openings **260** and **265** are formed, the insulation layer **160** may be divided into a plurality of first insulation patterns **165** each extending in the second direction, and the fourth sacrificial layer **170** may be divided into a plurality of fourth sacrificial patterns **175** each extending in the second direction.

A plurality of fourth openings **265** may be spaced apart from one another in the second direction between the third openings **260** neighboring in the third direction, each of which may extend in the second direction, and the second division pattern **235** may be formed between the fourth openings **265** neighboring in the second direction. Thus, even though a height of an upper surface of the mold is high and a length of the mold extending in the second direction is long, the fourth opening **265** does not extend to end portions in the second direction of the mold. A plurality of fourth openings **265** are spaced apart from one another in the second direction and the second division pattern **235** is formed therebetween, and thus the mold may not be bent or fall down in the third direction.

A first spacer layer may be formed on sidewalls of the third and fourth openings **260** and **265** and the third insulating interlayer **240**, and may be anisotropically etched to remove portions of the first spacer layer on bottoms of the third and fourth openings **260** and **265**, so that a first spacer **250** may be formed and that an upper surface of the first support layer **150** may be exposed.

The exposed portion of the first support layer **150** and a portion of the sacrificial layer structure **140** thereunder may be removed to enlarge the third and fourth openings **260** and **265** downwardly. Thus, the third and fourth openings **260** and **265** may expose an upper surface of CSP **100**, and further extend through an upper portion of the CSP **100**.

12

In exemplary embodiments of the inventive concept, the first spacer **250** may include undoped amorphous silicon or undoped polysilicon. However, if the first spacer **250** includes undoped amorphous silicon, the first spacer **250** may be crystallized by heat generated during deposition processes for other layers so as to include undoped polysilicon.

Referring to FIGS. **12** and **13**, the sacrificial layer structure **140** exposed by the third and fourth openings **260** and **265** may be removed by, e.g., a wet etching process to form a first gap **270**.

The wet etching process may be performed using, e.g., hydrofluoric acid or phosphoric acid.

When the sacrificial layer structure **140** is partially removed, sidewalls of the third and fourth openings **260** and **265** may be covered by the first spacer **250**, and thus the insulation patterns **165** and the fourth sacrificial patterns **175** of the mold may not be removed.

As the first gap **270** is formed, a lower surface of the first support layer **150** and an upper surface of the CSP **100** may be exposed. Additionally, a portion of a sidewall of the charge storage structure **190** may be exposed by the first gap **270**, and the exposed portion of the sidewall of the charge storage structure **190** may be also removed during the wet etching process to expose an outer sidewall of the channel **200**. Accordingly, the charge storage structure **190** may be divided into an upper portion extending through the mold and covering most of the outer sidewall of the channel **200**, and a lower portion covering a bottom surface of the channel **200** on the CSP **100**.

When the first gap **270** is formed, a portion of the second division pattern **235** at substantially the same height as the sacrificial layer structure **140** may be also removed to form a second gap **275**.

Referring to FIGS. **14** and **15**, the first spacer **250** may be removed, a channel connection layer may be formed on the sidewalls of the third and fourth openings **260** and **265** and in the first and second gaps **270** and **275**, and for example, an etch back process or a wet etching process may be performed to remove portions of the channel connection layer in the third and fourth openings **260** and **265**, so that the channel connection pattern **280** may be formed in the first gap **270**.

During the etch back process or the wet etching process, a portion of the channel connection layer in the second gap **275** may be also removed; however, the inventive concept may not be limited thereto. Thus, in some cases, the portion of the channel connection layer in the second gap **275** may remain as the channel connection pattern **280** therein.

As the channel connection pattern **280** is formed, the channels **200** in each channel group may be connected with one another, and if the channel connection pattern **280** remains in the second gap **275**, the channels **200** in each channel block may be connected with one another via the channel connection pattern **280**.

The channel connection pattern **280** may include, e.g., amorphous silicon doped with n-type impurities, and may be crystallized by heat generated during deposition processes for other layers, so as to include polysilicon doped with n-type impurities.

The air gap **285** may be formed in the channel connection pattern **280**.

Referring to FIGS. **16** and **17**, a second spacer **290** may be formed on the sidewalls of the third and fourth openings **260** and **265** and the exposed upper surface of the CSP **100**, and a fifth sacrificial layer **295** may be formed on the second spacer **290** to fill the third and fourth openings **260** and **265**.

13

If the channel connection pattern **280** does not remain in the second gap **275**, the second spacer **290** may be also formed on lower and upper surfaces and sidewalls of the second gap **275**, and a remaining portion of the second gap **275** may be filled with the fifth sacrificial layer **295**.

The second spacer **290** may include a nitride, e.g., silicon nitride, and the fifth sacrificial layer **295** may include, e.g., polysilicon.

Referring to FIGS. **18** and **19**, the second support layer **300** may be formed on the third insulating interlayer **240**, the second spacer **290**, and the fifth sacrificial layer **295**, and may be partially etched to form the fifth and sixth openings **310** and **315**.

In exemplary embodiments of the inventive concept, the fifth opening **310** may overlap in the first direction the third opening **260** in which the second spacer **290** and the fifth sacrificial layer **295** are formed, and a plurality of fifth openings **310** may be spaced apart from one another in the second direction on each of the third openings **260**. In an exemplary embodiment of the inventive concept, the fifth opening **310** may have a width in the third direction greater than that of the third opening **260**; however, the inventive concept may not be limited thereto.

In exemplary embodiments of the inventive concept, the sixth opening **315** may overlap in the first direction the second division pattern **235** and the fourth opening **265** in which the second spacer **290** and the fifth sacrificial layer **295** are formed, and a plurality of sixth openings **315** may be spaced apart from one another in the second direction on the second division pattern **235** and the fourth opening **265**. In an exemplary embodiment of the inventive concept, the sixth opening **315** may have a width in the third direction greater than those of the fourth opening **265** and the second division pattern **235**; however, the inventive concept may not be limited thereto.

In an exemplary embodiment of the inventive concept, the sixth opening **315** may overlap in the first direction opposite portions of the fourth openings **265** neighboring in the second direction and the second division pattern **235** therebetween.

In exemplary embodiments of the inventive concept, the fifth and sixth openings **310** and **315** may be arranged in a zigzag pattern in the second direction. The fifth and sixth openings **310** and **315** may partially overlap each other in the third direction.

Referring to FIGS. **20** and **21**, the second spacer **290** and the fifth sacrificial layer **295** in the third and fourth openings **260** and **265** may be removed through the fifth and sixth openings **310** and **315**, and thus the third and fourth openings **260** and **265** may be formed again.

Even though the third and fourth openings **260** and **265** are formed again, upper ends of the third and fourth openings **260** and **265** may be at least partially covered by the second support layer **300**. Thus, even though the mold has a high upper surface and a long extension length in the second direction, the mold may not be bent or fall down in the third direction due to the second support layer **300** at least partially covering an area of the third and fourth openings **260** and **265**.

In exemplary embodiments of the inventive concept, the second spacer **290** and the fifth sacrificial layer **295** may be removed by a wet etching process, and if the second spacer **290** and the fifth sacrificial layer **295** are formed in the second gap **275**, they may be also removed to form the second gap **275** again.

The fourth sacrificial patterns **175** exposed by the third and fourth openings **260** and **265** may be removed to form

14

a third gap **320** between the insulation patterns **165** at respective levels, and a portion of an outer sidewall of the charge storage structure **190** may be exposed by the third gaps **320**.

In exemplary embodiments of the inventive concept, the fourth sacrificial patterns **175** may be removed by a wet etching process using phosphoric acid or sulfuric acid.

Referring to FIGS. **22** and **23**, a second blocking layer **330** may be formed on the exposed portion of the outer sidewall of the charge storage structure **190**, inner wall of the third gaps **320**, surfaces of the insulation patterns **165**, a sidewall of the first support layer **150**, a sidewall of the channel connection pattern **280**, an upper surface of the CSP **100**, a sidewall and a portion of an upper surface of the third insulating interlayer **240**, and a sidewall and an upper surface of the second support layer **300**. A gate electrode layer may be formed on the second blocking layer **330**.

If the second gap **275** is formed again, the second blocking layer **330** and the gate electrode layer may be formed in the second gap **275**.

The gate electrode layer may include a gate barrier layer and a gate conductive layer sequentially stacked. The gate barrier layer may include a metal nitride, and the gate conductive layer may include a metal.

The gate electrode layer may be partially removed to form a gate electrode in each of the third gaps **320**. In exemplary embodiments of the inventive concept, the gate electrode layer may be partially removed by a wet etching process. If the second blocking layer **330** and the gate electrode layer are formed in the second gap **275**, the gate electrode layer may be removed.

In exemplary embodiments of the inventive concept, the gate electrode may extend in the second direction, and a plurality of gate electrodes may be formed in the first direction to form a gate electrode structure. The gate electrode structure may have a staircase shape including step layers of the gate electrodes.

Additionally, a plurality of gate electrode structures may be formed in the third direction, and may be spaced apart from one another by the third and fourth openings **260** and **265** and the second division pattern **235**. The gate electrode structure may include the first, second, and third gate electrodes **342**, **344**, and **346** sequentially stacked in the first direction. In exemplary embodiments of the inventive concept, the first gate electrode **342** may be formed at a lowermost level, and may serve as a ground selection line (GSL). The third gate electrode **346** may be formed at an uppermost level and a second level from above (e.g., below the uppermost level), and may serve as a string selection line (SSL). The second gate electrode **344** may be formed at a plurality of levels between the first and third gate electrodes **342** and **346**, and may serve as a word line.

Referring to FIGS. **1**, **24**, and **25**, a third division layer may be formed on the second blocking layer **330** to fill the third to sixth openings **260**, **265**, **310**, and **315**, and the third division layer and the second blocking layer **330** may be planarized until an upper surface of the second support layer **300** may be exposed to form the third and fourth division patterns **350** and **355** and the second blocking pattern **335**.

The third division pattern **350** may fill the third and fifth openings **260** and **310**, and may extend in the second direction. The first upper portion **350b** filling the fifth opening **310** may have a width in the third direction greater than that of the first lower portion **350a** filling the third opening **260**, and a plurality of first upper portions **350b** may

15

be spaced apart from one another in the second direction on the first lower portion **350a** extending in the second direction.

The fourth division pattern **355** may fill the fourth and sixth openings **265** and **315**. The second upper portion **355b** filling the sixth opening **315** may have a width in the third direction greater than that of the second lower portion **355a** filling the fourth opening **265**. The second lower portion **355a** may extend in the second direction, but may be partially cut by the second division patterns **235**. The second upper portions **355b** may be spaced apart from one another in the second direction on the second lower portions **355a** and the second division patterns **235**.

If the second blocking layer **330** is formed in the second gap **275** and the gate electrode layer is removed from the second gap **275**, the protrusion portion **355c** of the fourth division pattern **355** may be formed in a remaining portion of the second gap **275**.

Referring back to FIGS. **2A**, **2B**, and **3**, the fourth insulating interlayer **360** may be formed on the second support layer **300**, the third and fourth division patterns **350** and **355**, and the second blocking pattern **335**, and the contact plug **370** may be formed through the third and fourth insulating interlayers **240** and **360** and the second support layer **300** to contact an upper surface of the capping pattern **220**.

A fifth insulating interlayer may be formed on the fourth insulating interlayer **360** and the contact plug **370**, and the upper wiring **380** may be formed through the fifth insulating interlayer to contact an upper surface of the contact plug **370**. The upper wiring **380** may serve as a bit line of the vertical memory device. In exemplary embodiments of the inventive concept, the upper wiring **380** may extend in the third direction, and a plurality of upper wirings **380** may be spaced apart from one another in the second direction.

The vertical memory device may be manufactured by the above-described processes.

As illustrated above, even though the mold has a high upper surface and a long extension length in the second direction, due to the second support layer **300** at least partially covering an upper end of the third opening **260** extending through the mold and extending in the second direction, and the second division pattern **235** between the fourth openings **265** each extending through the mold spaced apart from one another in the second direction, the mold may not be bent or fall down in the third direction.

FIGS. **26** and **27** are plan views illustrating vertical memory devices in accordance with exemplary embodiments of the inventive concept. The vertical memory devices may be substantially the same as that of FIGS. **1** to **3**, except for some elements. Thus, like reference numerals refer to like elements, and detailed descriptions thereof are omitted herein.

Referring to FIG. **26**, the fourth division pattern **355** may include the second lower portions **355a** spaced apart from one another in the second direction and connected to the second division patterns **235**, and the second upper portions **355b** contacting upper surfaces of the second lower portions **355a**, respectively.

In this case, the first and second upper portions **350b** and **355b** of the third and fourth division patterns **350** and **355**, respectively, may be arranged in a zigzag pattern in the second direction or in the third direction, and the first upper portions **350b** of each of the third division patterns **350** may overlap in the third direction the second upper portions **355b** of the fourth division patterns **355**.

16

Referring to FIG. **27**, the fourth division pattern **355** may include the second lower portions **355a** spaced apart from one another in the second direction and connected to the second division patterns **235**, and the second upper portions **355b** spaced apart from one another in the second direction and contacting upper surfaces of the second lower portions **355a**, respectively.

In this case, the first and second upper portions **350b** and **355b** of the third and fourth division patterns **350** and **355**, respectively, may be arranged in a zigzag pattern in the second direction or in the third direction, and the first upper portions **350b** of each of the third division patterns **350** may overlap in the third direction the second upper portions **355b** of the fourth division patterns **355**.

FIGS. **28** to **30** are plan views illustrating vertical memory devices in accordance with exemplary embodiments of the inventive concept. The vertical memory devices may be substantially the same as that of FIGS. **1**, **26**, and **27**, except for some elements. Thus, like reference numerals refer to like elements, and detailed descriptions thereof are omitted herein.

Referring to FIGS. **28** to **30**, a plurality of fourth division patterns **355** may be spaced apart from one another in the third direction between the third division patterns **350** neighboring in the third direction.

In other words, the fourth division patterns **355** spaced apart from one another in the second direction may form a fourth division pattern column, and a plurality of fourth division pattern columns may be spaced apart from one another in the third direction between the third division patterns **350** neighboring in the third direction.

As described above, the vertical memory device in accordance with exemplary embodiments of the inventive concept may include second to fourth division patterns between gate electrode structures, and a second support layer on the gate electrode structures. Thus, the gate electrode structures may not be bent or fall down.

While the inventive concept has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by one of ordinary skill in the art that variations in form and detail may be made thereto without departing from the spirit and scope of the inventive concept as set forth by the appended claims.

What is claimed is:

1. A vertical memory device comprising:

gate electrode structures each including gate electrodes spaced apart from one another on a substrate in a first direction substantially perpendicular to an upper surface of the substrate, wherein each of the gate electrodes extends in a second direction substantially parallel to the upper surface of the substrate, and the gate electrode structures are spaced apart from one another in a third direction substantially parallel to the upper surface of the substrate and crossing the second direction;

channels each extending through one of the gate electrode structures in the first direction;

a first division pattern extending in the second direction between first ones of the gate electrode structures neighboring in the third direction;

second and third division patterns alternately disposed in the second direction between second ones of the gate electrode structures neighboring in the third direction; and

a support layer on the gate electrode structures, wherein the support layer is at substantially the same height as

17

upper portions of the first and second division patterns and contacting the upper portions of the first and second division patterns,

wherein the upper portions of the first division pattern are spaced apart from one another in the second direction; and

wherein the upper portions of the first division patterns and the upper portions of the second division patterns are arranged in a zigzag pattern in the second direction in a plan view.

2. The vertical memory device of claim 1, wherein each of the upper portions of the first division patterns partially overlaps the upper portions of the second division patterns in the third direction.

3. The vertical memory device of claim 1, wherein the first division pattern is one of a plurality of first division patterns spaced apart from one another in the third direction, and

wherein the second division pattern is disposed between neighboring first division patterns of the plurality of first division patterns neighboring in the third direction.

4. The vertical memory device of claim 3, wherein the second division pattern is one of a plurality of second division patterns spaced apart from one another in the third direction between the neighboring first division patterns.

5. The vertical memory device of claim 1, wherein the first division pattern includes a lower portion extending in the second direction, and

wherein each of the upper portions of the first division pattern contact an upper surface of the lower portion of the first division pattern.

6. The vertical memory device of claim 5, wherein a width in the third direction of each of the upper portions of the first division pattern is greater than that of the lower portion thereof.

7. The vertical memory device of claim 5, wherein a distance of the upper surface of the lower portion of the first division pattern from the substrate is greater than a distance of an upper surface of the third division pattern from the substrate.

8. The vertical memory device of claim 5, further comprising a metal oxide pattern covering a sidewall of each of the upper portions of the first division pattern.

9. The vertical memory device of claim 8, further comprising a blocking pattern covering lower and upper surfaces and a sidewall of each of the gate electrodes,

wherein the blocking pattern includes a material substantially the same as that of the metal oxide pattern.

10. The vertical memory device of claim 1, wherein the second division pattern includes lower portions spaced apart from one another in the second direction and connected to the third division patterns, and

wherein the upper portions of the second division pattern contact upper surfaces of the lower portions, respectively.

11. The vertical memory device of claim 1, wherein the second division pattern includes lower portions spaced apart from one another in the second direction and connected to the third division patterns, and

wherein the upper portions of the second division pattern are spaced apart from one another on each of the lower portions, and each contact an upper surface of a corresponding one of the lower portions.

12. A vertical memory device comprising:

gate electrode structures each including gate electrodes spaced apart from one another on a substrate in a first direction substantially perpendicular to an upper sur-

18

face of the substrate, wherein each of the gate electrodes extends in a second direction substantially parallel to the upper surface of the substrate, and the gate electrode structures are spaced apart from one another in a third direction substantially parallel to the upper surface of the substrate and crossing the second direction;

channels each extending through one of the gate electrode structures in the first direction;

a first division pattern extending in the second direction between first ones of the gate electrode structures neighboring in the third direction;

a second division pattern and a third division pattern alternately disposed in the second direction between second ones of the gate electrode structures neighboring in the third direction; and

a support layer on the gate electrode structures, wherein the support layer is at substantially the same height as upper portions of the first and second division patterns and contacting the upper portions of the first and second division patterns,

wherein the second division pattern includes lower portions spaced apart from one another in the second direction and connected to the third division patterns, and

wherein the upper portions of the second division pattern commonly contact upper surfaces of neighboring lower portions of the second division pattern in the second direction.

13. The vertical memory device of claim 12, wherein the third division pattern overlaps the lower portion of the second division pattern in the first direction.

14. The vertical memory device of claim 12, wherein a width in the third direction of the upper portion of the second division pattern is greater than that of the lower portions thereof.

15. The vertical memory device of claim 12, wherein a distance of upper surfaces of the lower portions of the second division pattern from the substrate is greater than a distance of an upper surface of the third division pattern from the substrate.

16. A vertical memory device comprising:

gate electrode structures each including gate electrodes spaced apart from one another on a substrate in a first direction substantially perpendicular to an upper surface of the substrate, wherein each of the gate electrodes extends in a second direction substantially parallel to the upper surface of the substrate, and the gate electrode structures are spaced apart from one another in a third direction substantially parallel to the upper surface of the substrate and crossing the second direction;

channels each extending through one of the gate electrode structures in the first direction;

a first division pattern including:

a first lower portion extending in the second direction between first ones of the gate electrode structures neighboring in the third direction to separate the first ones of the gate electrode structures from one another; and

first upper portions spaced apart from one another in the second direction, and contacting an upper surface of the first lower portion;

a second division pattern including:

second lower portions spaced apart from one another in the second direction and disposed between second ones of the gate electrode structures; and

19

second upper portions contacting upper surfaces of the second lower portions;
third division patterns disposed between the second lower portions of the second division pattern; and
a support layer on the gate electrode structures, and facing 5
sidewalls of the first and second upper portions of the first and second division patterns, respectively.

17. The vertical memory device of claim 16, wherein the first and second upper portions of the first and second division patterns, respectively, are at substantially the same 10
height.

18. The vertical memory device of claim 16, wherein widths in the third direction of the first and second upper portions of the first and second division patterns, respectively, are greater than widths in the third direction of the 15
first and second lower portions of the first and second division patterns, respectively.

* * * * *

20